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Industrial Sector Technology Use Model (ISTUM):

Industrial Energy Use In The United States, 1974-2000.

Volume 4. Technology Appendix

Final Report

October 1979

MASTER

U.S. Department of Energy
Assistant Secretary for Fossil Energy

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PREFACE

This is the fourth volume of the ISTUM (Industrial Sector Technology Use Model) documentation. The first volume of the report describes the model logic and the data inputs. The second volume lists and evaluates the results of one model run. The third volume gives detailed information on the energy demand data base. This volume gives information on the individual technology specifications.

Chapter II of volume I presents a discussion of the technologies that compete in the ISTUM model. The emphasis in Chapter II, volume I is on providing an overview of where each technology fits into the general model logic. This volume presents the actual cost structure and specification of every technology modeled in ISTUM.

The first chapter of volume IV presents a general overview of the ISTUM technology data base. It includes an explanation of the data base printouts and how the separate cost building blocks are combined to derive an aggregate technology cost. The remaining chapters are devoted to documenting the specific technology cost specifications.

This volume should not be considered a self standing document. It is supplementary to Chapter II of Volume I, and much information relevant to a technology's specification is presented only in Volume I. To achieve an understanding of the cost structure of any of the technologies Chapter I of this volume, and the discussion of conventional coal steam (technology

8.11) should be read first. The documentation of conventional coal steam is presented in the greatest depth and it serves as a guide to the documentation of all the other technologies.

Note: Due the printer's requirements, the color sheets referenced for General Information (yellow, page I-6), Technology Specifications (green, page I-10), and Building Blocks (pink, page I-14) have been printed on white sheets.

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CHAPTER I

A. Introduction

In devising a methodology for technology evaluation the following goals were considered to be important:

- To portray the costs associated with a specific energy technology as accurately as possible.
- The methodology should be general enough to allow for a consistent and systematic application across different technologies.
- It should allow for easy cost sensitivity analysis.
- It should provide information on the interdependencies among the different technologies.

The technology characterization system presented in Volume I, chapter II is based upon the division of a technology's overall cost into separate cost building blocks. If several technologies have common cost components, such as coal handling, then the same building block is used in the specification of each technology to insure consistency. The use of the cost building blocks also makes for easy cost sensitivity analysis by compartmentalizing the costs. This system allows for easy identification of the cost structure of any technology and easy modification of the mix of building blocks or cost components of a technology if additional information becomes available.

One of the distinctive features of the ISTUM model is the use of cost distributions for each technology as opposed to the use of a point cost estimates. The use of these cost frequency distributions results in a closer approximation of reality and incorporate more information into the evaluation process. Table (I-1) lists factors causing this cost variability.

Estimating these capital cost distributions presented several problems specific to this methodology. Most of the data available incorporated only single point cost estimates, usually a good site condition and no unusual circumstances are assumed. Our methodology requires examination of bad sites, with unusual circumstances. Most of this cost information had to be generated through our own resources. Normally technology cost estimates assume favorable conditions and an application where there is a reasonable expectation that the technology will be economically viable. This procedure leads to examining s biased sample, and consequently a restricted range of costs. The ISTUM model requires the consideration of costs associated with <u>all</u> the potential applications of a technology within its defined market. This includes applications where the technology is usually not even considered, i.e., where it would be rejected a priori as being too expensive. By considering costs for an entire population of potential applications, a much wider range of costs are obtained.

In developing our technology cost distributions the highest priority went to the development of a cost evaluation system that allows maximum flexibility in testing different scenarios or estimates. With some 150 technologies to be evaluated in a three month time period, absolute truth was beyond our grasp. Of course, in developing our characterizations of energy technologies the most current data available from DOE program offices, recent studies and private vendors was used. To account for the fact that the data available on some technologies was much stronger than what was available on others, a data quality coding system was developed to roughly rank the confidence one could have in the costing of any particular technology.

TABLE I-1

PARTIAL LIST OF SOURCES OF TECHNOLOGY COST VARIABILITY

A. Application Related Variability

1. Specific process requirements. These may vary within a service sector. For example some direct heat applications may require more uniform heat distribution, which is accomplished by increasing the number of burners resulting in higher costs. Another example is steam, where pressure and temperature requirements vary with application.

2. Turndown requirements. Batch processing or discontinuous shipments of raw materials may call for equipment that can respond to rapidly changing loads.

3. Reliability requirements. Some industries place a high premium on reliability. The value of lost output due to equipment failure may make it economic to have complete backup systems.

B. Site Related Variability

1. Available Space. A lack of available space can greatly increase the cost of certain technologies, particularly solar where collector space is needed, and coal where room for coal handling is required.

2. Local variables. Such as the cost of the land, costs of obtaining required permits and costs related to environmental restrictions.

TABLE I-1 continued

3. Weather. Harsh weather increases coal handling costs, and amount of sunlight (insolation) is important for solar costs.

4. Terrain - Rugged, sloped or marshy land can increase construction costs.

5. Auxiliary costs. Some technologies require considerable water and/or electricity. Their cost and availability varies from site to site. Boiler feedwater and electricity for coal handling equipment are examples.

6. Labor wages and productivity variability. Wage rates and labor productivity vary from site to site.

C. Firm Related Variability

1. Cost of Capital. Different firms have different financial structures.

2. Operator and maintenance skill levels.

3. Familiarity with technology being installed. Do they have past experience with this type of system?

4. Planning Horizon and general organization.

Note: Technical uncertainty is not incorporated into the cost variability. It is a separate issue. ISTUM assumes for example, that any technical barriers preventing the use of an energy technology are overcome, and at reasonable cost.

B. Guide to the Technology Data Base

In developing the technology data base the trade off between model size and better specification of technology inputs was constantly confronted. The present model contains over twelve thousand cost inputs for the one hundred and fifty six technologies. To keep the data base at a manageable size only one set of building blocks was used for each technology, even where there was more than one size and load factor specified. This one set of building blocks was then scaled up or down to reflect the costs of the technology at different sizes. When possible the building blocks from one technology were used to specify the cost distributions of other, different technologies.

The first section of this guide describes the three sets of inputs required to characterize a technology in the ISTUM model. This is followed by an example showing how the building blocks are combined, and how the mean value of the overall distribution is calculated. The third section discusses the estimation of the building block frequencies.

1. ISTUM Technology Inputs

The multi-colored sheets contain all the ISTUM technology inputs. Three sets of information were required for each technology: general information (yellow sheets), technology specifications (green sheets) and the list of relevant building blocks (white sheets).

a. General information inputs (yellow sheets)

The general inputs consists of three pages of information for each technology. Reading from left to right these sheets contain the following information:

i) The technology name and identification number. The first two digits of the I.D. number identify the technology and the next one or two digits identify the service sector. I.D.'s 1.11 and 1.112 refer to atmospheric fluidized bed combustion in service sectors 1 and 12 respectively. Table I-2 presents a list of service sectors.

ii) Year available - This refers to the first year of commercial availability, the date at which actual energy production can occur. A more complete discussion is in Volume I, p. II-18.

iii) Fuels used - Two fuels can be specified for one technology. The coding is as follows:

1 - coal
2 - oil
3 - natural gas
4 - electricity
5 - industrial waste
6 - waste heat
7 - process change
8 - sunlight
9 - biomass
10 - geothermal
11 - wind
12 - uranium
13 - not specified

iv) Fuel Share - This is the fraction of Btu's of fuel consumed represented by the first fuel listed under fuels used. This value can be greater than one or even negative for some cogeneration and conservation technologies that either save fuel or provide other fuel credits such as electricity resulting from cogeneration.

v) Fuel Efficiency - Three efficiencies can be listed: combustion, transmission and final use. These three efficiencies are multiplied times each other to determine a technology's overall efficiency. Some heat pump technologies may have efficiencies greater than one. If a technology has two fuels, the efficiency listed is for the first fuel only.

vi) Size Range - This is a mechanism for restricting a technology to a limited size range. The technology is applicable to all sizes within the range.

vii) Load Range - This serves the same function as as the size range, only it refers to hours of operation.

viii) Maximum Fraction - Three maximum fractions are listed:

Incremental - This refers to the fraction of incremental demand that can be served by a technology. Factors that can restrict the incremental market available to a technology are discussed in Volume I, p II-17.

Retrofit - Since this version of ISTUM does not deal with retrofit applications, the retrofit maximum fraction is always zero.

Conservation - This refers to technologies that improve efficiency. For example, if a conservation technology improves the efficiency of a process by ten percent then even if all applications adopt this technology it would only supply 10 percent of that service sectors energy demands. Therefore its maximum market fraction is placed at ten percent.

To calculate a technology's overall maximum fraction the incremental and conservation maximum fractions are multiplied times each other. For most conservation technologies the conservation and incremental maximum fractions were combined outside the model resulting in only an incremental maximum fraction being listed. The conservation technology writeups in Chapter VI break out these separate maximum fractions.

ix) Service Sector - This identifies what service sector this technology is competing in. A list of service sectors is presented in Table I-2.

x) Data Quality - A data quality coding system Table I-3 was developed to roughly rank the confidence one could have in a particular estimate. Four different factors were given data quality codes: the maximum fraction, the cost, the energy savings for conservation technologies and the DOE acceleration.

The grouping of technologies into these different categories required some subjective judgement. The goal was to be consistent in our evaluation of each technology.

xi) Construction Period - This is an estimate of the length of time required for the installation of that specific energy technology in years.

xii) Physical Life - This is an estimate of the physical life of the energy technology equipment in years.

xiii) DOE Acceleration - This is an estimate of the effect of DOE programs on the date of commercial availability for that technology in years.

xiv) Applicable Industries - The third page lists the industries that can be served by that particular energy technology within a service sector. See Chapter (Volume 1) IV.B.3)

b) Technology Specifications (green sheets)

The technology specification sheets list the building blocks that are used to specify each technology. It also includes the building block coefficients that adjust the costs in the building blocks to those appropriate for the sizes specified in that service sector. When there is more than one column of size coefficients the column on the left always refers to the smaller size. (The size coefficients are not labeled as to the size they represent. These can be found in Table (Vol. 1) III-13).

TABLE I-2

SERVICE SECTORS USED IN THE ISTUM MODEL

1. Steam*
2. Direct Heat - (Intermediate)*
3. Direct Heat - (Dirty)*
4. Indirect Heat - (coal capable)*
5. Machine Drive*
6. Electrolytic*
7. Liquid Feedstock
8. Natural Gas Feedstock
9. LPG Feedstock
10. Metallurgical Coal
11. Miscellaneous Energy and Lubes
12. Space Heat*
13. Indirect Heat - (not coal capable)*
14. Calcining*
15. Glass Melting*
16. Brick and Clay Firing*
17. Ironmaking*
18. Steelmaking
19. Steel Reheating*
20. Internal Generation
21. Captive Electricity
22. Captive Direct Heat
23. Coke Consumption

* indicates service sectors in which technologies compete in ISTUM. The remaining service sectors are maintained to keep an accurate accounting of total energy consumption in the industrial sector.

TABLE I-3

DATA QUALITY CODES

Quality Code A

1. Strong supporting technology specification including component break down according to typology system. (It should be recognized that in conservation there are some single component technologies).

2. Some physical hardware development at least at "bench scale" level to validate operating characteristics.

3. Review by EEA to assure consistency of specifications with ISTUM requirements.

4. No structural modeling problems. I.e., the technology is well suited for the ISTUM model logic.

Quality Code B

1. Good data but deficient in at least one category "A" element. This deficiency cannot be deemed a severe problem.

2. The technology is not a radical departure from existing commercial technologies with which it competes.

Quality Code C

Marginal technology in most or all Category "A" elements

1. Little engineering evaluation and specification.
2. No hardware development.
3. Insufficient EEA review.
4. Serious but not fatal modeling problems.
5. Technology is a fairly radical departure from existing commercial technologies.

TABLE I-3 continued

Quality Code D

Technology inputs inadequate for modeling in ISTUM.

1. No engineering development.
2. No EEA review.
3. Proposer data - not validated.

OR 4. Fatal modeling problems.

c. Building Blocks (pink sheets)

The white sheets contain a list of all the building blocks required by the technology specification sheets. The information contained in a building block is as follows:

i) Size of unit costed out (MMBtu/hr) - This refers to the service demand size of the technology unit for which the costs in the building block are appropriate without adjustment.

ii) Type - There are three building block types. Type "S" refers to the standard cost building block which is added to the other type "S" building blocks listed in the technology specification. A type "M" building block is a multiplicative building block. It is a table of scalers that are multiplied times each of the type "S" building blocks. The type "L" blocks are peculiar to the cogeneration and self generation technologies. These are costs that are incurred yearly and are not subject to the capital recovery factor. The demand charge for electricity is a specific example.

iii) Fraction of costs for O&M - This specifies the fraction of capital costs that are allocated to the operating and maintenance of the equipment or material contained in that building block. (Fuel costs are not included). All of the O&M costs are calculated for a load factor of 4000 hours. To determine O&M costs for load factors other than 4000 hours an ex-

ponential scale factor is calculated.
The scale factor comes from the equation:

$$\text{scaler} = \left(\frac{\text{load factor}}{4000}\right)^{.83}$$

4) Frequency and cost data - This information is not expressed in a form conducive to easy understanding. For the first building block listed in the conventional technology section we have:

A8.11 Site Preparation and Power House

frequency	cost
0.500	541.000
0.400	823.000
0.100	1,761.000
0.000	0.000

This table is in thousands of dollars and says that $541,000 is the lowest possible cost and that 50 percent of the possible applications will have a cost of between $541,000 and $823,000, 40 percent will have a cost of between $823,000 and $1,761,000, and that 10 percent will have a cost greater than $1,761,000. If "x" is defined to be the actual cost of a particular application then:

estimated frequency	range
.00	$x < \$541,000$
.50	$\$541,000 \leq x < \$823,000$
.40	$\$823,000 \leq x < \$1,761,000$
.10	$\$1,761,000 \leq x$

2. Sample Calculations

To help promote an understanding of how this building block format works to construct an overall cost distribution, the mean $/MMBtu cost of one of the overall cost distributions will be calculated.

The mean cost for technology 8.31, natural gas boilers, will be derived for the 50 MMBtu/hr size and 4000 hr. load factor.

From the green computer printout sheets the technology specification for 8.31 is:

Technology I.D. 8.31

Block I.D.	Name	Block Coeff.	Size Coeff.	Size Coeff.
A8.11	Site Prep. - Powerhouse	.46	.57	2.10
B8.11	Boiler Equip. and Controls	.29	.53	2.30
C8.11	Fuel Handling	.50	.64	1.80
E8.11	Utilities	.70	.59	2.00
H8.11	Indirect Capital Costs	1.00	1.00	1.00
I8.11	Regional Cost Index	1.00	1.00	1.00

Step 1 - The first step is to adjust the costs in the building blocks listed in the Block I.D. column to costs relevant for the natural gas technology sized at 50 MMBtu/hr steam produced. This involves multiplying each of the capital costs listed in the building block by the product of the block coefficient and the appropriate size coefficient. This is done for building block A8.11 below. Please note that all costs are in thousands of dollars.

Site Prep. - Powerhouse

Original A8.11

Type: S, O&M: .03

Adjusted A8.11

Type: S O&M: .03

cost x block coeff. x size coeff.

Freq.	Cost
.5	541
.4	823
.1	1,761
0	0

→

$$\begin{bmatrix} 541 \times .46 \times .57 \\ 823 \times .46 \times .57 \\ 1,761 \times .46 \times .57 \end{bmatrix}$$

→

Freq.	Cost
.5	142
.4	216
.1	461
0	0

The same procedure for each of the other building blocks yields the adjusted building blocks:

B 8.11 Boiler Eq.

Type: S, O&M: .115

Freq.	Cost
.35	231
.55	323
.10	387
0	0

C8.11 Fuel Handling

Type: S, O&M: .12

Freq.	Cost
1.0	149

E8.11 Utilities

Type: S, O&M: .07

Freq.	Cost
.20	87
.50	107
.30	273
0	0

H8.11 Indirect Cap. Costs

Type: M, O&M: .0

Freq.	Cost
.55	1.3
.35	1.4
.10	1.5
.0	1.65

I8.11 Regional Variation

Type: M, O&M: .0

Freq.	Cost
.4	.87
.4	.97
.2	1.07
0	1.25

Step 2 - The mean capital cost of each building block must be calculated. To calculate the mean of the distribution of a particular building block the following equation is used:

$$\mu \text{ cap. cost} = \text{freq. } 1 \ \frac{\text{Cost } 1 + \text{Cost } 2}{2} + \text{freq. } 2 \ \frac{\text{Cost } 2 + \text{Cost } 3}{2} + \text{freq. } 3 \ \frac{\text{Cost } 3 + 1.2 \times \text{Cost } 3}{2} ;$$

where the building blocks are in the following form:

frequency	capital cost
freq. 1	cost 1
freq. 2	cost 2
freq. 3	cost 3
0.000	0.000

The value 1.2 x Cost 3 is used in the last term of the equation to put an upper limit on the distribution. The 1.2 is an arbitrarily picked factor. This 1.2 factor is not used on type M building blocks where the end value is specified. This will become clear in the example.

The mean values for each building block are calculated as:

$$\text{mean A8.11} = .5 \ \frac{142 + 216}{2} + .4 \ \frac{216 + 461}{2} + .1 \ \frac{461 + 1.2(461)}{2}$$

$$= 275.6$$

$$\text{mean B8.11} = .35 \ \frac{231 + 323}{2} + .55 \ \frac{323 + 387}{2} + .1 \ \frac{387 + 1.2(387)}{2}$$

$$= 334.8$$

$$\text{mean C8.11} = 149$$

$$\text{mean E8.11} = .2 \ \frac{87 + 107}{2} + .5 \ \frac{107 + 273}{2} + .3 \ \frac{273 + 1.2(273)}{2}$$

$$= 204.5$$

$$\text{mean H8.11} = .55\ \frac{1.3 + 1.4}{2} + .35\ \frac{1.4 + 1.5}{2} + .1\ \frac{1.5 + 1.65}{2}$$

$$= 1.41$$

$$\text{mean I8.11} = .4\ \frac{.87 + .97}{2} + .4\ \frac{.97 + 1.07}{2} + .2\ \frac{1.07 + 1.25}{2}$$

$$= 1.01$$

Step 3 - The determination of the mean operations and maintenance cost. Only the type S blocks have O&M costs.

mean O&M A8.11 = 275.6 x .03 =	8.27	thousand dollars/year
mean O&M B8.11 = 334.8 x .115 =	38.50	
mean O&M C8.11 = 149 x .12 =	17.88	
mean O&M E8.11 = 204.5 x .07 =	14.31	
TOTAL	78.96	

Step 4 - The mean capital costs are added together. The total mean capital cost is found by multiplying the mean indirect capital cost value (1.41) times the sum of the type S block costs:

275.6 + 334.8 + 149 + 204.5 = 963.9 thousand dollars

Total capital cost = (963.9) (1.41) = 1,359.1

These are costs in 1977. For later years capital cost escalators are used. See Volume 1, Ch. VI.

Step 5 - An annual cost must be calculated. A capital recovery factor of .12 is used to annualize the total capital costs. This capital recovery factor will vary depending upon the construction period and life of the equipment.

(total capital cost x cap. recovery factor) + O&M = annual cost

($1,359.1) x .12 + $78.96 = $242,052 per year

Step 6 - The annual cost is multiplied by the regional indices:

$242,052/yr x 1.01 = $244,472

Step 7 - The annual costs are expressed dollars per million Btu's of service demand.

$$\text{annual cost} \times \frac{1}{\text{load factor}} \times \frac{1}{\frac{\text{MMBtu}}{\text{hr}}\ \text{produced}} = \$/\text{MMBtu}$$

$$\$244{,}472/\text{yr.} \times \frac{1\ \text{yr}}{4000\ \text{hrs}} \times \frac{1}{50\ \text{MMBtu/hr}} = \$1.22\ \text{MMBtu}$$

This value of $1.22 MMBtu is the mean annual capital and operating cost of the overall distribution. Figures I-1 and I-1(b) illustrate how the total cost distribution for a technology is derived.

III. Estimation of Building Block Frequencies

Some reviewers of the ISTUM methodology have expressed the view that a weakness of the model is that it requires frequency distributions for the building block cost cases and that these distributions, by their very nature, are highly subjective. Actually the reverse is true. The use of these frequency estimates, even though they are somewhat subjective, is a strength of the model and represents another advantage of this methodology over the use of point estimates.

Every point estimate has an implicit frequency incorporated into it. This is made apparent when the estimator states that this is an "average" cost, or that this estimate assumes "good" or "normal" conditions. Other conditions which in fact often occur are not considered. What these statements mean to the estimator may be very different from the interpretation given to them by the reader. The ISTUM methodology makes these implicit frequencies explicit, and it goes even further by giving information on what occurs in cases other than the ideal case.

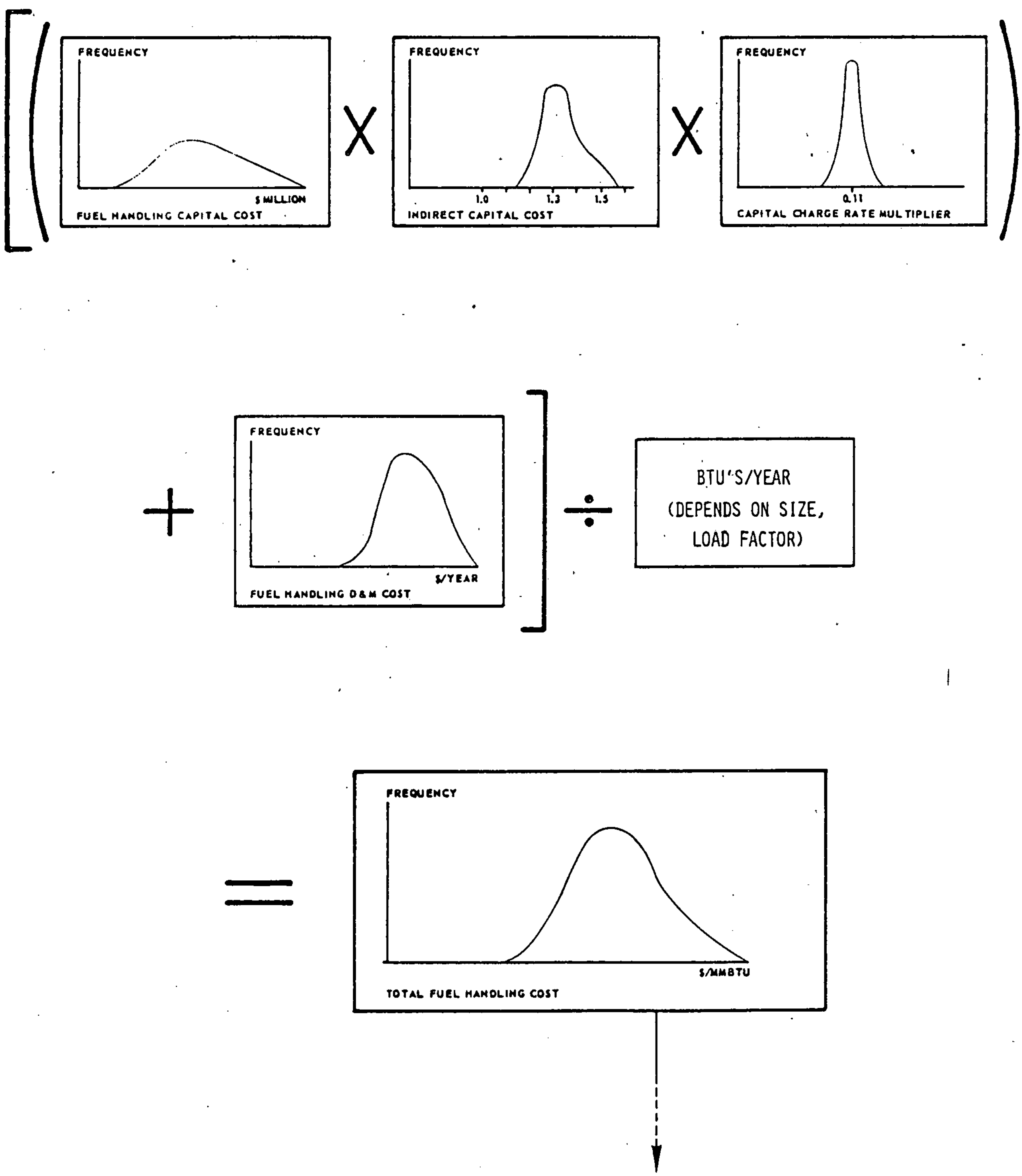
The process of quantifying individual judgement concerning the liklihood of various scenarios or outcomes has long played an important role in decision analysis. A sizeable body of literature and many different techniques have developed over the years.[1/] The procedure used to generate the ISTUM frequency estimates first required the determination of the relevant cost cases and the overall range of the distribution. A set of frequency estimates were generated independently by different EEA engineers and staff members. The people involved in the estimation procedure have all participated in surveys and site visits to different industrial plants as well as having worked in the field for a number of years. These estimates were supplemented by conversations with vendors of the various equipment components. When certain building block frequency estimates differed radically from person to person outside sources were consulted. For the most part, the frequency estimates made by each person were quite similar.

To the extent that this project is a first effort in this area and that a wide range of technologies were covered in a very short time, there is no question that many refinements and improvements can be made in both the frequency and cost estimates.

1/ A useful article for our purposes was "Probability Encoding in Decision Analysis," by C.S. Spetzler and C.S. Von Holstein, in Management Science, Vol. 22, November 1975.

FIGURE I-1

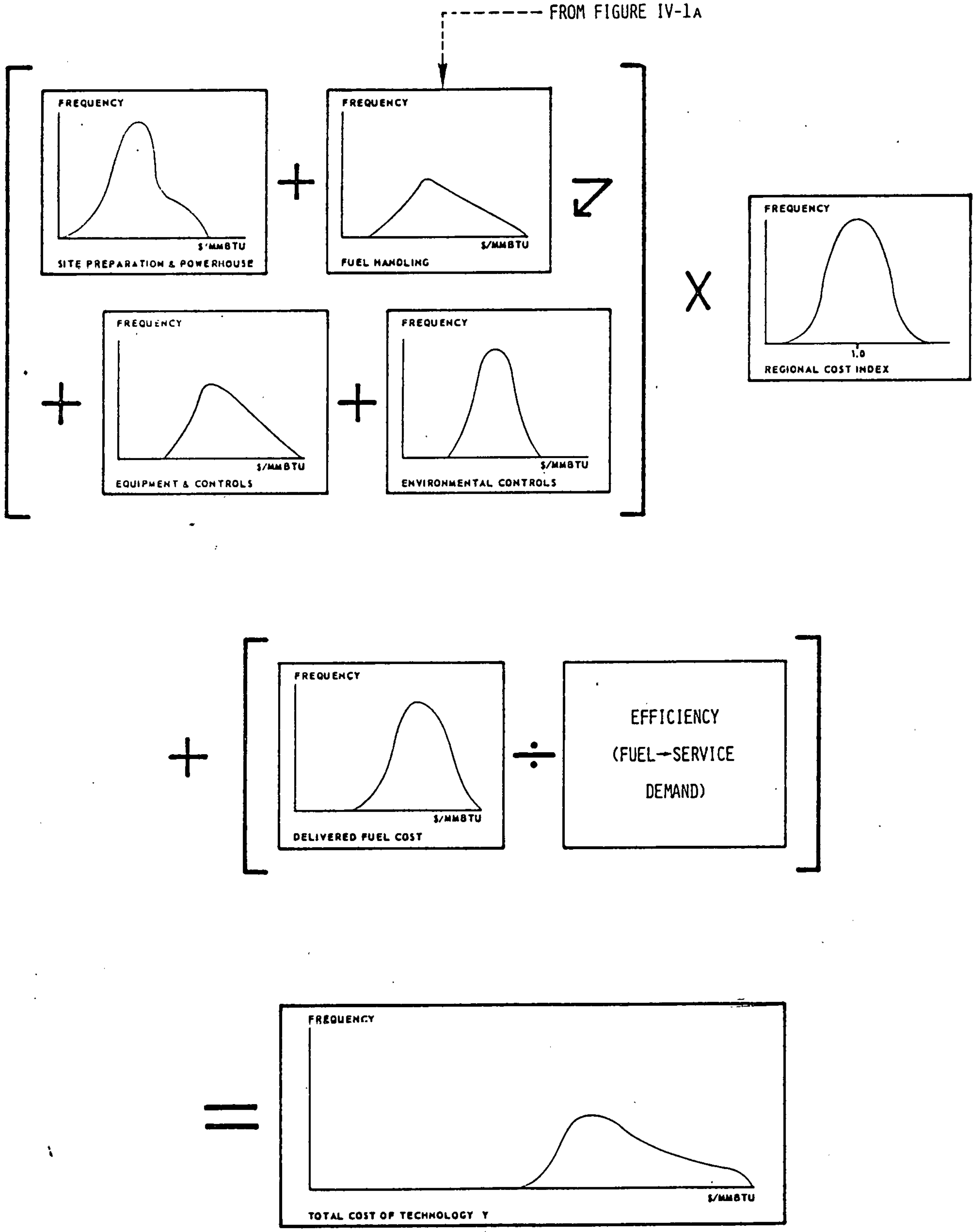
DERIVING TOTAL COST DISTRIBUTION FOR TECHNOLOGY Y:
Adding Fuel, Operating, and Capital Costs for One Building Block



TO FIGURE IV-1B

FIGURE I-1(b)

DERIVING TOTAL COSTS COMBINING COST COMPONENTS



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CHAPTER II

CONVENTIONAL TECHNOLOGIES

A. Introduction

The conventional technologies are comprised of technologies that are currently being used or, if they are considered unproven,[1/] are new applications of basically conventional techniques. Most service sectors have three competitive conventional technologies: conventional natural gas, conventional oil and conventional coal. Several service sectors have additional conventional technologies that utilize process by-products. Wood and black liquor boilers in steam and the use of captive gas in steel reheat applications are examples. It is convenient to segment the conventional technologies into two groups, boiler related technologies and non-boiler technologies. The boiler technologies are those in the steam and space heat service sectors. All other service sectors represent non-boiler applications.

A substantial amount of information is available on the costs of the conventional steam technologies, however very little information is available for most of the non-boiler applications. Where many sources were used to determine the costs of the conventional steam systems, we were forced to rely primarily on one source for the non-boiler technologies.

The boiler technologies, service sectors 1 and 12 are presented first. Technology 8.11 conventional coal steam is documented in the greatest detail. To obtain a thorough understanding of the estimation procedure used for any of the conventional technologies the documentation of conventional coal steam should be read first.

1/ Unproven conventional technologies are discussed in Volume I, Chapter II.

B. Boiler Technologies

The boiler related technologies comprise the steam and space heat service sectors. The technologies in the steam service sector are discussed first.

1. Conventional Coal Steam - ID 8.11

Conventional coal steam is the technology documented in the greatest detail. To avoid repetition, many of the calculations that were required for the cost estimation of every technology are documented only for conventional coal steam. The costs calculated for this technology provide the basis for the cost structure of all the coal technologies.

DISCUSSION OF BUILDING BLOCKS

a. Building Block A8.11
Site Preparation and Power House

The costs in this building block reflect:

- the cost of the overall site preparation
- the cost of the power house, including the stack
- the cost of land and appropriate permits
- miscellaneous site and yard work
- site related costs occuring in other cost components[1/]

The building block contains costs for a coal steam system sized at 120 MMBtu/hr of steam production. The costs are in mid-1977 dollars. When required, escalation factors were obtained from <u>Chemical Engineering</u> magazine's plant indices.

1/ This last item reflects site related interdependence among the separate building blocks. Including these costs in the site preparation is adjusts for these interdependencies.

i. Best Case (low cost)

The best case occurs when no significant site constraints exist. The site is sufficient in area and design to allow for straightforward construction of the power house and supporting facilities.

Clearing, Grading and Leveling

The amount of land required for a coal boiler system including room for the coal handling equipment, is estimated to be one acre for every 100,000 lbs/hr steam output,[1/] or approximately 120 MMBtu/hr of service demand. From the examination of several topographical maps it was found that a normal to good site would have an average slope of five degrees.

Assuming a square site, the area would be 69.57 x 69.57 yards. The following approximation procedure is used to calculate the required amount of cut and fill material (see Figure II-1).

The amount of cut and fill material required is:

.5(34.78)(69.75)(3.13) = 3796.5 cubic yards (c.y.).

The estimated cost of cut, fill and compacting is $1.60/c.y.[2/]. The total cost for cutting and fill is $1.60 x 3796.5 c.y. = $6,074.

1/ Based on information from "Estimates of Costs of Conventional Coal-Fired Steam Production Plants," United Engineers and Constructors, Inc., Union Carbide Subcontract No. 4484, June 1977.

2/ Gutherie, Kenneth M., Process Plant Estimation, Evaluation and Control, Craftsman Book Co., 1974

The estimated cost of general clearing is \$.92 square yard (s.y.)[1/], .92 x 4840 = \$4,451 for clearing.

The cost of final grading and leveling is \$.95 s.y.[2/] or a total of \$4,607.

The total cost of site preparation for a good site is then:

\$6,074 + 4,451 + 4,607 = \$15,132.

An estimate of \$15,000 is used in the model.

Power House Costs (best case)

A boiler house for a 120 MMBtu/hr boiler is estimated to need a 45 ft x 60 ft floor and require a ceiling 60 ft high[3/] A control room 25 ft. x 25 ft. is also included in this estimate. Gutherie[4/] was used as the source for

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1/ Ibid.

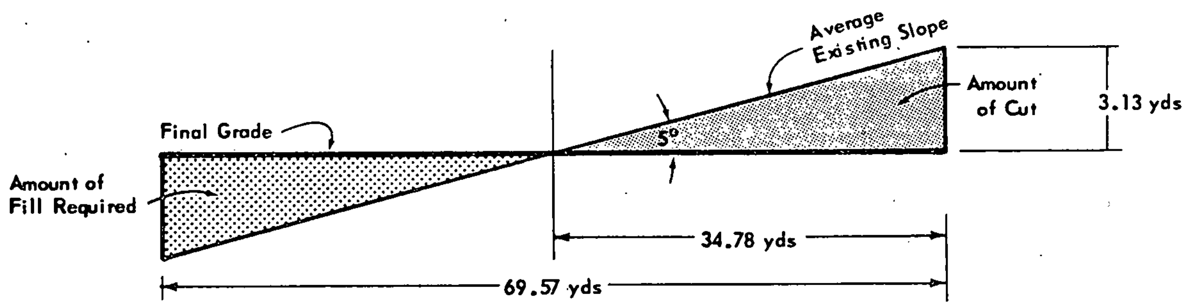
2/ Ibid.

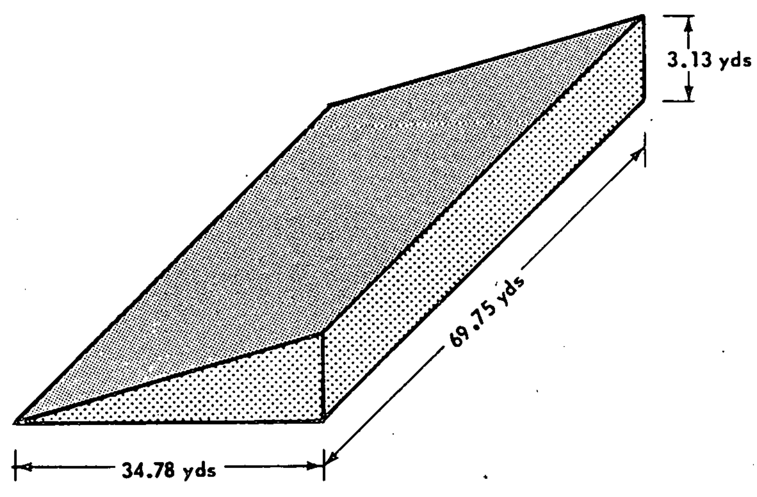
3/ Based on boiler dimensions from Babcock and Wilcox, Steam/ It's Generation and Uses, 1975 and Coffin, Dwight, "Estimate the Cost of Your Next Coal-Fired Boiler," Power, Oct. 1977.

4/ Op. Cit.

FIGURE II-1

APPROXIMATION OF REQUIRED CUT AND FILL MATERIAL





THE AMOUNT OF CUT AND FILL MATERIAL REQUIRED IS: .5(34.78)(69.75)(3.13) = 3796.5 Cubic Yards these cost estimates. The appropriate building 10 ft. high is estimated at $14.67 per square foot of floor space. To increase the height to 60 ft. a multiplicative factor of 4 is used. The cost of the building shell is ($14.67)(2700 ft^2) (4) = $158,436.

Other costs:

Lighting and Electric:	$4.51/$ft^2$
Heating and Ventilating:	$2.00/$ft^2$
Fire Prevention[1/]:	$2.34/$ft^2$
TOTAL:	$8.85/$ft^2$ x 2700 ft^2 = $23,895

The total cost of the power house is: 158,430 + $23,895 = 182,331.

For the control room we have:
625 ft^2 x ($14.67/$ft^2$ + $8.85/$ft^2$) = $14,700.

Certain steel and concrete supporting structures are required for the boiler, coal bunker and stack. These costs are estimated at $1.13 per cubic foot of space. (45 x 60 x 60) ($1.13) = $183,060. This cost includes the steel support structure, concrete footings for the boiler, checker plate, stairways, and handrails.

The total cost of the power house, control room and support structures is:

$182,331 + 14,700 + 183,060 = $380,000

To calculate the subcontracting fees, Gutherie (5) suggests a markup of 1.176 for the power house and control room,

1/ Reflects costs of alarms, sprinklers and extinguisher.

and 1.19 for the support structures. An approximation of 1.18 was used in this analysis. The final cost is $380,000 x 1.18 = 448,400 (approximately $450,000) This estimate assumes a simple concrete slab foundation for the power house.

Land And Permit Costs (best case)

An estimate of $5,000 per acre is used as the cost of land. Permit costs were estimated at $90,000 and includes the actual cost of the permits as well as any legal fees incurred during the application process. A wide range of permits may be necessary. Building, zoning and pollutant emission or disposal permits can be required. Both land and permit costs are subject to significant variations. In this analysis point estimates were used. In the future it may be more appropriate to model these costs as another component or building block to capture this distribution.

Miscellaneous Site and Yard Work

Items falling into this category are:

surveying:	$500
fencing:	$2,000
gravel access roads:	$2,000
sewer connections:	$3,000
other:	$2,500
TOTAL -	$10,000

Final Costs for the Best Case

a)	Cutting and fill, grading, leveling	$ 15,000
b)	Power house and boiler support structure	$450,000

c)	Land and permit costs	$ 95,000
d)	Misc. site and yard work	$ 10,000
e)	Site costs of other components (to be added on later)	--
	TOTAL	$570,000

Adjustments for Plant Type (low cost)

In our initial cost estimation for conventional coal, oil and gas technologies we looked at the three different plant types: a new plant case, an existing plant using a different energy technology, and an existing plant currently using the proposed energy technology. These plant cases are discussed more explicitly in Volume I.[1/] It was felt that when the power system was being installed along with a new plant certain construction economies of scale would be realized. The required materials would be purchased as part of a larger order and all the required labor and equipment would already be at the site. This was assumed to result in a fifteen percent savings in the construction of the power house and since the site preparation for the coal boiler system can be done at the same time as the rest of the plant a savings of 33 percent was assumed.

For a plant that currently exists and is using an energy technology other than conventional coal no savings on any of these factors was assumed.

For an existing plant currently using coal and facing no severe land constraint it was assumed that the existing coal storage facilities could be expanded reducing the amount of site preparation required. A 33 percent savings in site preparation was assumed in this case.

1/ This is discussed in Vol. 1 Chap. 2. p. II-6.

ii. Medium Cost Case

The medium cost case is the result of moderate site difficulties in the form of sloped or rugged terrain. Also, the layout of the land may pose some problems by requiring an unusual equipment configuration.

Clearing, grading and leveling (medium cost)

The medium cost case assumes an effective average slope of 25^{o}. Computation similar to the low cost case of a 5^{o} slope yields a total cost of cut, fill and compacting of $29,036. The cost of general clearing is assumed to be 10 percent more expensive than the low cost case as a result of rougher terrain. The cost of final grading and leveling is the same as in the low cost case. Total clearing, grading and leveling is $29,036 + 4,896 + 4,607 = 38,539. An approximation of $40,000 was used as the estimate.

Power House Costs (medium cost)

The medium cost case calls for a powerhouse with a more extensive foundation. Instead of a simple concrete slab foundation, a concrete floor with ten foot deep piers to footing is assumed. A multiplicative factor of 1.12 is used by Gutherie to estimate the increased cost of the building shell due to the more extensive foundation. The cost of the supporting structures remains the same.

Subcontracting multiplier (Foundation multiplier (power house) + control room + support structures) = total powerhouse cost

1.18 (1.12 ($182,000) + $14,700 + $183,000) = $473,817
An estimate of $470,000 is used.

Land and Permit Costs

Land and permit costs are assumed to be the same as in the low cost case.

TABLE II-1

Best Case - Site Preparation and Power House Costs
(in thousands of 1977 dollars)

	New Plant	Existing Plant different technology	Existing Plant same technology
Clearing, grading and leveling	10	15	10
Power House and support structures	385	450	450
Land and permit costs	95	95	95
Miscellaneous site and yard work	10	10	10
TOTAL	500	570	565

TABLE II-2

Medium Cost - Site Preparation and Power House Costs
(thousands of 1977 dollars)

	New Plant	Existing Plant Different Technology	Existing Plant Same Technology
Clearing, grading and leveling	$ 30	$ 40	$ 30
Power house and support structures	400	470	470
Land and permit costs	95	95	95
Miscellaneous site and yard work	15	15	15
TOTAL	$540	$620	$610

Miscellaneous Site and Yard Work (medium cost)

This cost is increased from $10,000 to $15,000 to account for the increased site difficulties.

Adjustments for Plant Type (medium cost)

Construction economies of scale in the new plant case are assumed to result in a 15 percent reduction in the cost of the power house and a 25 percent reduction in the costs of clearing, grading and leveling. The existing plant currently using coal is assumed to extend its current coal storage area resulting in a 25 percent decrease in site preparation costs.

iii. High Cost Case

The high cost case occurs where significant site difficulties hamper construction or expansion. Steeply sloped land, rugged terrain, marshy soil or simply a lack of available land can increase costs.

For the new plant case it was assumed that unstable soil conditions required elaborate foundations. (see Figure II-2) There are sixteen footings and each footing is assumed to be supported by six piles. The cost for 32 ten inch square, thirty foot long precast concrete piles installed is estimated at $40,000 from Richardson[1/]. This includes pile caps, ties and testing.

The high cost case for existing plants occurs when significant site difficulties hamper expansion. This may present a situation where it is cost effective to remove the old boilers to make room for the new coal boilers. The usual case is to expand the powerhouse to enclose the new boilers retaining the old boilers as backups or for peak load use. Often the old

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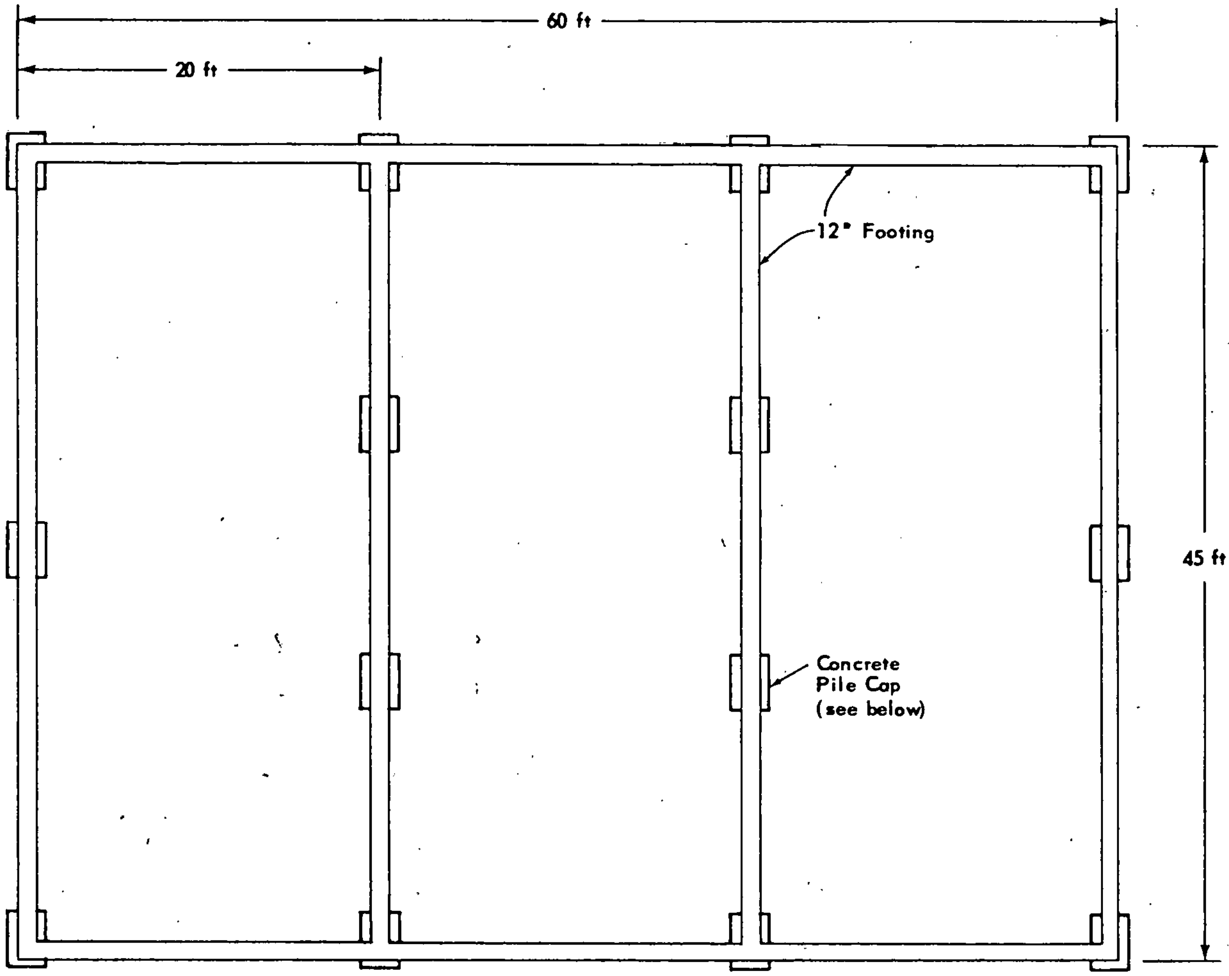
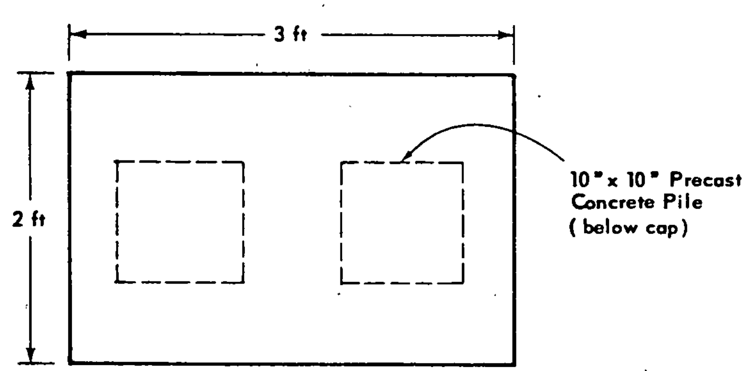
1/ Richardson Engineering Services, Inc., The Richardson Rapid System, Process Plant Construction and Estimating Standards, 1977-78 edition.

FIGURE II-2

PLAN OF POWERHOUSE FOOTING



PLAN OF POWER HOUSE FOOTING



PLAN OF PILE CAP

concrete footings cannot be used for the new boilers. In a plant that previously burned oil or gas some expansion of the power house may still be required. Allowing enough height for the coal bunkers is often the greatest concern. Additional modifications must be made to the power house such as installing heavy beams to support the coal bunkers. The alternative is to try and overcome the site difficulties and extend the power house to cover the new boilers, retaining the old boilers as backups.

iv. Operating and Maintenance Costs

The operating and maintenance costs were estimated as three percent of the total capital cost. Operating and maintenance costs ranged from $15,000 to $24,000 per year. They include general maintenance of the power house and grounds.

v. Construction of the Final Distribution

Initally costs were constructed for all three plant type cases, the new plant case and the two existing plant cases, for all the conventional and fossil energy technologies in the steam service sector. It was found that when the cost components were combined, the final cost distributions for each of the plant type cases were very similar[1/]. Each plant case had somewhat offsetting cost advantages and disadvantages. To reduce the data storage requirements the three plant types were combined into one distribution. Through support work done for the national energy plan,[2/] the relative frequencies of each plant case

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1/ Additional information in Volume I, Book I, chapter II.

2/ "Industrial Coal Conversion Model" for the Office of Policy and Evaluation, DOE, by Energy and Environmental Analysis, Inc., in progress.

TABLE II-3

High Cost Case - Site Preparation and Power House Costs

(thousands of 1977 dollars)

	New Plant	Existing Plant	
		Different Technology	Same Technology
Clearing, Grading, leveling and piles	$ 70	80	80
Power House and Support Structure	420	600	520
Land and permit costs	95	95	95
Miscellaneous site and yard work	20	20	20
TOTAL	$605	$795	$715

was estimated. In 1978-85 it was estimated that 40 percent of the coal boiler systems will be installed in new plants, 50 percent will be in existing plants that formerly burned oil or gas and 10 percent will be in plants that are expanding their coal capability. However, these relative frequencies will not remain constant over time. As more industries begin to use coal the number of existing plants converting from oil or gas to coal will decline and the number of coal burning facilities that expand will be increasing. Also there are some plants currently using oil or gas that formerly burned coal and still have some coal capable equipment on hand. Consideration of all of these factors resulted in frequency estimates of .4 for new plants, .4 for existing plants, different technology and .2 for existing plants, same technology.

To reduce these three plant type cases in Table II-4 to one aggregate case the following calculation is required:

.4 (new plant cost) + .4 (existing, different technology cost) + .2 (existing plant, same technology cost) = aggregate cost

For example the aggregate low cost would be:

$.4(500) + .4(570) + .2(565) = 541.$

The same calculation is performed for the medium and high costs.

The resulting aggregate distribution for the site preparation and power house costs is presented in Table 5.

TABLE II-4

SITE PREPARATION AND POWER HOUSE COSTS

Site Preparation and Power House Costs A8.11	NEW PLANTS			Existing Plants					
				Different Technology			Same Technology		
	freq.1/	capital	O&M	freq.	capital	O&M	freq.	capital	O&M
Low Cost	.50	500	15	.50	570	17	.50	565	17
Medium Cost	.40	540	16	.40	620	19	.40	610	18
High Cost	.10	605	18	.10	795	24	.10	715	21

1/ Please refer to Chapter 1 section B.3 for the frequency estimation procedure.

vi. Site Related Costs Incurred by Other Components

The procedure used to construct the overall technology cost distribution from the separate building blocks assumes that each building block is independent of the others. However, interdependencies do exist among the building blocks. A site problem that makes construction of the power house more expensive will also tend to increase the costs of the coal handling system. Also, severe land constraints can increase costs across all components by making installation more expensive due to crowded working and storage conditions.

To reduce the amount of interdependence resulting from site related factors two adjustments were made. First, the variability in coal handling costs was found to be primarily site related[1/]. To compensate for this interdependence the cost differential between the low and medium coal handling costs is incorporated into the medium site preparation costs, and the cost differential between medium and high coal handling costs is incorporated into the high site preparation costs.

Building Block C8.11 - Coal Handling (thousands of $'s)

low capital cost -	$467	
medium capital cost	$547	$80 difference
high capital cost	$897	$430 difference

The coal handling component is then expressed as a point estimate of $467,000. All the cost variability associated with coal handling is shifted to the site preparation and power house component. This procedure eliminates the site related interdependence between the site preparation and power house building block and the coal handling building block by arranging the costs so that site related variability occurs in just one building block.

1/ Please see the write-up in this section on building block C8.11 for additional information.

The second adjustment to the site preparation and power house component results from site related factors that increase the installation cost of equipment. A land constraint resulting in crowded, cramped working conditions will increase the costs of installing the major equipment components. To incorporate this cost into the site preparation component, it was assumed that moderate site difficulties increase installation costs by ten percent and severe site difficulties increase installation costs by up to forty percent. These two factors were added on to the medium cost and high cost site preparation cases.

Discussions with vendors indicated that installation costs were roughly one third of the total installed cost. As an approximation of installation cost, one third of the medium cost case was used for the major equipment components.

medium cost, boiler equipment	2,100,000
medium cost, environmental equipment	2,340,000
medium cost, auxiliary equipment	260,000
TOTAL	4,700,000

4,700,000/3 = 1,566,600 is the estimate of major equipment installation costs. Ten percent of estimated installation costs is $157,000 and forty percent is $628,000.

Incorporating these two adjustments into the site preparation costs yields the following costs for the site preparation and power house costs (see Table II-6).

This procedure reduces the site related interdependence between separate building blocks, but it tends to introduce other errors. Combining cases from different building blocks affects the frequency estimates as well as the costs. In the

TABLE II-5

AGGREGATE SITE PREPARATION AND POWER HOUSE COSTS

A 8.11 Site Preparation and Power House	Aggregate Case freqency	capital costs	O&M
Low cost	.5	541	16
Medium cost	.4	586	18
High cost	.1	703	22

TABLE II-6

ADJUSTED SITE PREPARATION AND POWER HOUSE COSTS
(thousands of 1977 dollars)

Capital costs A8.11	Site prep. power house	coal ad-justment	installation adjustment	total
best case	541	0	0	541
moderate case	586	80	157	823
difficult case	703	430	628	1761

base case the same frequencies estimated for the unadjusted A8.11 (table 5) were used for the adjusted site preparation and power house building block (table 6). This introduced some bias into the analysis. The high cost case of coal handling results from the need to store coal in silos. Silo storage of coal can result from factors other than a land constraint. Regulations against fugitive dust, or harsh weather conditions can require silo storage. This gives silo storage of coal a greater frequency of occurance than what was estimated for the difficult site case. In the next model run this bias will be corrected.

b. Building Block B8.11
Coal Boiler Equipment

This building block includes the costs of the boiler drum, coal feed and hopper, fans, economizer, instrumentation and controls. The cost of boiler equipment is one cost component that is essentially independent of whether the system is being installed in a new or existing plant.

The primary source of cost variation in coal boiler equipment is the need to install multiple units to meet a single demand. A multiple boiler system most often results from a need for system reliability. Increased reliability is provided by maintaining backup equipment, each sized at a fraction of peak load. Also, limited turndown capabilities of a single boiler make multiple boiler systems more efficient when demand varies widely. When demand is low, most of the steam drums can be shut down, and the remaining drums run near full capacity.

Another cost factor is the boiler instrumentation and control system. The choice is between automatic control or a more manual system, however the cost variation among control systems is minimized when operating and maintenance costs are added to the capital costs.

Other factors that can affect boiler equipment costs are the pressure-temperature requirements and the type of coal used. The cost effects of higher pressure-temperature requirements were obtained to develop cost estimates for the cogeneration technologies.[1/] Discussions with manufacturers indicated that the boiler costs associated with meeting different pressure and temperature steam demands resulted in only a five

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1/ See the cogeneration of treatment incremental boiler costs Book I, p. II-56.

percent variation in the overall equipment cost.[1/] A similar cost variation was found in boilers designed to burn different coal types, lignite excluded. An industrial boiler study[2/] obtained costs for boilers designed to burn four coal types with Btu content ranging from 9,500 Btu/lb to 12,000 Btu/lb and ash content from 9 percent to 14 percent. Their boiler equipment cost estimates varied by less than three percent across the different coal types.

The explicit cost variation accounted for in building block B8.11 is assumed to be the result of the demand for boiler redundancy. The data sources for these estimates were several EEA reports[3,4/] and additional vendor estimates.

1/ This cost insensitivity is partially a by-product of the units in which the boiler size is measured. ISTUM uses service demand units of MMBtu's per hour produced. Lower boiler pressures and temperatures decrease the Btu content per pound of steam requiring more steam to maintain the service demand size. These are offsetting cost factors. The lower pressures and temperatures result in less expensive boiler equipment, but a larger capacity is required to meet the service demand output.

2/ Unreleased draft report, prepared for the Office of Policy and Evaluation, Department of Energy.

3/ "Industrial Boiler Study" prepared for the Federal Energy Administration, by Energy and Environmental Analysis, Inc., December 1977.

4/ "Coal Utilization in the Paper Industry, prepared for the Department of Energy, by Energy and Environmental Analysis, Inc. February 28, 1978.

To cross check our estimates the actual costs of five boiler units installed in the past two years were obtained.

i) Best Case - low cost

One boiler is installed that provides 100 percent of the required steam capacity. Building block B8.11 is sized at a steam demand of 120 MMBtu/hr. One boiler capable of producing 120 MMBtu/hr of steam is estimated to cost $1.5 million.

ii) Medium Cost Case

This is a multiple system of two 60 MMBtu/hr boilers each providing 50 percent of the required capacity. Discussions with vendors resulted in a rough estimate of $2.1 million, or 40 percent more expensive than a single boiler system. The more expensive cost for paired boilers is the result of duplication of many of the parts and the scale economies associated with boiler drums and tubing at these industrial sizes.

iii) High Cost Case

This is represented by a multiple system of three 40 MMBtu/hr boilers each supplying one third of the steam demand. This results in a 20 percent cost increase over the cost of the two 50 percent capacity boilers, i.e., a cost of $2.52 million.

In addition to installing redundant equipment, reliability concerns may result in some plants installing overcapacity. For example, instead of having a multiple boiler system with two 50 percent capacity boilers, two 70 percent capacity boilers may be installed. Then if one boiler goes down the plant can still operate at 70 percent capacity. Since we are using continuous distributions, the correct interpretation of the medium cost case says that 55 percent of new boiler installations will have a cost between $2.1 million and $2.52 million dollars. Multiple boiler systems with overcapacity can be assumed to comprise the top end of this cost range.

iv) Adjustments for Plant Type

The capital costs are assumed to be constant across plant types. However the frequency of occurrence is not. A new plant will usually install a multiple boiler system for reliability where an existing plant will usually expand by installing a single boiler retaining the old boiler or boilers as backup. In the plant design survey published in Power Magazin seven new, coal capable steam plants, and sixteen additions to existing plants were listed. All of the new plants installed multiple coal capable boilers, where only one of the existing plant expansions was a multiple system.

TABLE II-7

COAL BOILER EQUIPMENT COSTS

B8.11	New Plants		Existing Plants different technology		Existing Plants same technology	
	freq.	capital cost	freq.	capital cost	freq.	capital cost
low cost	.10	1,500	.55	1,500	.5	1,500
medium cost	.70	2,100	.40	2,100	.45	2,100
high cost	.20	2,520	.05	2,520	.05	2,520

The frequency and cost estimates for each plant case are listed in Table II-7. From the discussion on building block A8.11 recall that new plants have an estimated frequency of .4, the existing plant, different technology a frequency of

1/ "Industrial Steam", Power; Issues Nov. 1975, 1976, 1977.

.4 and the existing plant same technology .2. The aggregate frequencies for building block B8.11 are then:

low cost frequency =	.4(.10) + .4(.55) + .2(.5) = .36
medium cost frequency =	.4(.70) + .4(.40) + .2(.4) = .53
high cost frequency =	.4(.20) + .4(.05) + .2(.05)= .11

The estimates for operating and maintenance costs were taken directly from the <u>Industrial Boiler Study</u> prepared by Energy and Environmental Analysis.[1/] A relationship between O&M costs and capital costs was calculated as:

O&M \$/yr = .12(capital costs x load factor ratio) + 105,000

The load factor ratio is defined as the assumed load factor divided by 8000 hours a year. In the final application operating and maintenance costs were estimated at 11.5 percent of capital costs.

1/ <u>Op. cit.</u>

c. Building Block C8.11
Coal Handling Equipment

Most of the cost variation present in this building block is the result of different site conditions. The general layout and topography of the land can affect coal handling costs by increasing the distance or height the coal must be conveyed. A major problem for many plants is a shortage of land available for coal storage. To compensate, more efficient use of the land can be made by storing coal in silos, by having more frequent deliveries there by reducing the need to store coal on site, or the coal can be stored at a remote location and hauled to the boiler.

Other considerations would include environmental restrictions on coal dust which could require silo storage and covered conveyors. Harsh weather conditions such as heavy wind and rain could also require covered storage and conveyors. Cold weather resulting in frozen coal increases the cost of handling and unloading coal. Initially it was felt that reliability requirements resulting in redundant equipment could represent a significant cost variation. Consultation with industry representatives indicated that this cost variation was minimal. To achieve increased reliability the only change was in the size of the coal bunker. This provides a sufficient supply of coal to allow most coal handling equipment breakdowns to be repaired.

Coal is assumed to be delivered by rail or truck and will require:

- unloading
- storing
- reclaiming

The cost of each of these functions is dependent upon the quantity of coal consumed at the plant. The coal handling equipment is sized to meet the peak coal usage.

In the steam service sector two load factors, 4000 and 7000 hours of operation per year, are considered. They represent eleven hours and twenty hours of operation per day. These loads represent average operating conditions and it is possible that plants with a 4000 hour load factor may have short term peak loads where 20 hours per day of operation are required. As a result all equipment and coal storage costs are based on a 7000 hour load. Operating and maintenance costs are calculated separately for the two load factors.

The coal handling facility is designed for a steam system producing 120 MMBtu/hr of steam at a load factor of 7000 hours. A study of the paper industry prepared for the Department of Energy by Energy and Environmental Analysis[1/] contained an extensive analysis of coal handling costs. This provided the basis for the coal handling system presented here.

The coal handling system layouts were based upon information found in Steam[2/], the McNally Pittsburgh Coal Preparation

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1/ Coal Utilization in the Paper Industry, by Energy and Environmental Analysis Inc., prepared for the U.S. Dept. of Energy, February 28, 1978.

2/ Steam, Its Generation and Use, Babcock and Wilcox, 1975.

Manual, and EEA's engineering experience. An equipment inventory for the coal handling system is presented in Table II-8 with a side and overhead view presented in Figure II-3. The system provides for the coal to be unloaded, transferred to a conveyor belt which carries it to the coal pile. In a separate operation, coal is reclaimed from the pile, crushed and conveyed by belts to the bins within the powerhouse. The coal pile contains ten day's live storage and thirty day's dead storage. A nine inch thick limestone bed is spread under the pile as a drainage control technique. The system contains only the equipment necessary to deliver coal to the hopper in the power house. Equipment such as pulverizers, burners, scales, etc. are included in the boiler equipment.

A steam system providing 120 MMBtu's per hour with an efficiency of .82 will require 146 MMBtu's of coal an hour. Assuming a coal Btu content of 11,500 Btu's /lb then approximately 120 tons of coal is required for a 20 hour day. The coal handling system outlined in Figure II-3 allows for 900 tons of coal to be unloaded in six hours[1/]. Coal deliveries would be required approximately every seven days.

The capital cost data was obtained primarily by sending preliminary handling system layouts and equipment inventories to vendors. Cost estimates were provided for the majority of components, as well as estimates of installation and annual maintenance. Some component costs were estimated by EEA

1/ Four to six hours was quoted by Babcock and Wilcox in their Steam publication as the usual amount of time allowed for unloading, however some plants may chose to receive less frequent deliveries and increase the unloading time.

TABLE II-8

COAL HANDLING SYSTEM

Unloading Equipment #1 Equipment	Storage Equipment #2 Equipment	Reclaim Equipment #1 Equipment
(*) Car shaker - 1	(4) Belt 24" x 300' - 1 10 hp motor	(*) Vibratory electro 2 @ 20 tph magnetic feeders
(1) Hopper[2/] - 1 @ 10t	(5) Belt 24" x 140' - 1 10 hp motor	(8) Belt feeders - 2 @ 20 tph
(2) Vibratory Feeder - 1 @ 150 tph	(6) Tower dump - 1 48' high	(9) Belt 18" x 100' - 1 2 hp motor
(3) Belt Feeder - 1 @ 150 tph	(7) Coal Pile[3/] - 1 140' x 180' x 45'	(10) Belt 18" x 200' - 1 5 hp motor
		(*) Crusher - 1
		(*) Tramp iron - 1 magnot

Legend: ' - feet, "- inches
t - tons, tph - tons per hour, hp - horse power
* - not depicted in coal handling system diagrams

1/ Number refers to components identified in Figure II-3.

2/ Open hopper for truck delivery; undertrack hopper for rail deliveries.

3/ Underlined with 9 inches of limestone.

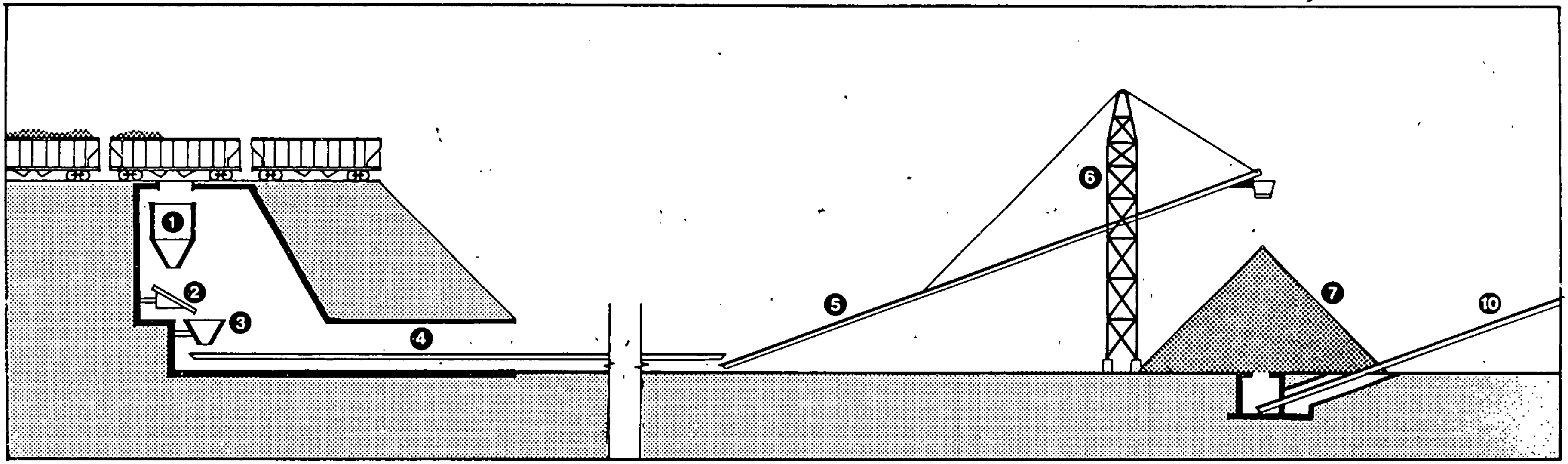
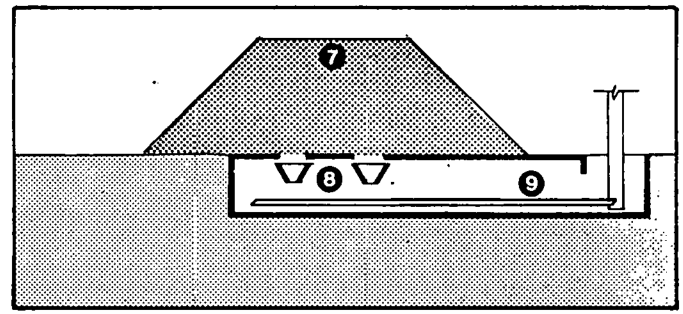
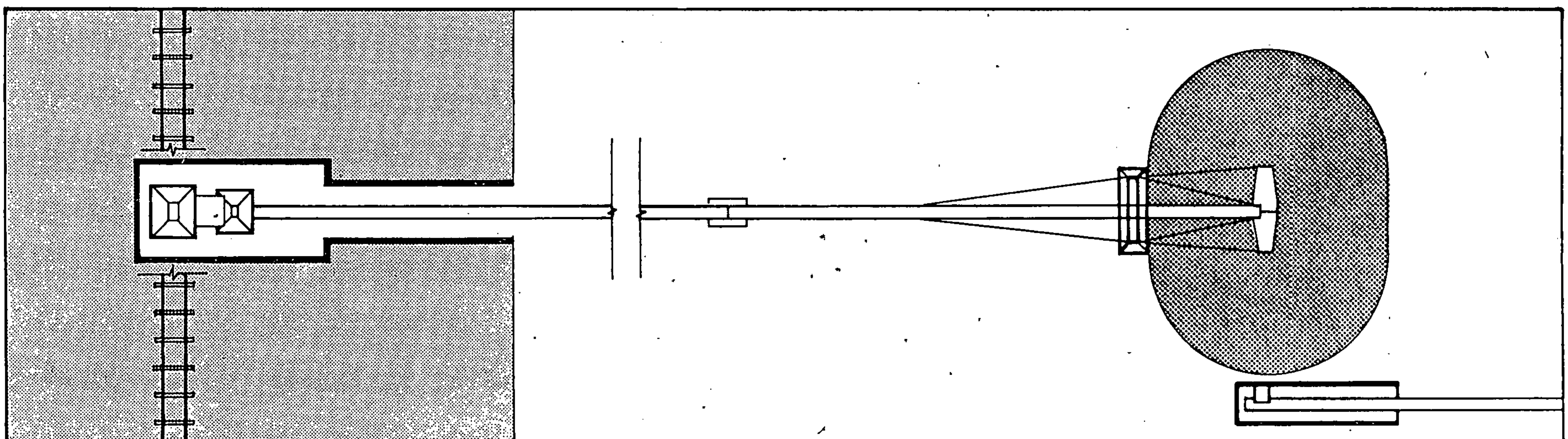


FIGURE II-3

COAL HANDLING SYSTEM #1

(NUMBERS REFER TO INFORMATION IN TABLES A-3 TO A-5)





staff based on recent editions of Engineering News Record[1/], equipment costs shown in the Cost Reference Guide[2/], and previous experience with related equipment.

i) Best case - low cost

The land is sufficient in area and layout so as not to provide any constraints on the design of the coal handling system. The costs of general clearing and grading are contained in building block A8.11, site preparation and power house, but other yardwork costs, including the drainage system, the limestone bed for the coal pile and treatment of coal pile runoff are charged to coal handling.

Estimated Capital Costs ($ thousands)

Unloading -	61
Storage -	168
Reclaim -	127
Stockpile -	111
TOTAL	$467

The stockpile costs are the costs associated with acquiring a one-month supply of coal. A cost of $1.40 per MMBtu of coal was used.

Stockpile calculations:

6 tons of coal are consumed per hour. A load factor of 7000 hrs/yr, and a Btu content of 23 MMBtu/ton of coal is assumed.

1/ Engineering News Record, McGraw Hill, New York, New York.

2/ National Research and Appraisal Company, Cost Reference Guide for Construction Estimating, Equipment Guide - Book Company, Palo Alto, California, 1976.

$$6 \text{ tons/hr} \times 7000 \text{ hrs/yr} \times \frac{1 \text{ yr}}{365 \text{ days}} \times 30 \text{ days} \times \frac{23 \text{ MMBtu}}{\text{ton}} \times$$

1.40 $/MMBtu = $111,000 the stock pile accumulation cost.

ii) Medium Cost Case -

The available land presents a moderate constraint by having the absolute quantity of land limited or by having undesirable topography. These items can increase the costs of storage and reclaiming the coal from the coal pile. Outdoor coal piles are still feasible.

iii. High Cost Case -

This case assumes that silo storage of coal is necessary. Several factors can result in silo storage being required. See figure II-4. Silos can be used to conserve on land area when the amount of land available is severely limited, harsh weather can result in physical degradation of the coal when it is stored outdoors, and environmental restrictions on fugitive dust, water pollution from coal pile runoff or the visual impact of the plant may result is silo storage of coal being desirable.

The estimated costs of silo storage were obtained from Richardson[1/]:

TABLE II-9

CAST-IN-PLACE CONCRETE SILOS

Material Density	Storage Capacity	Diam. x Height	Discharge Method	Estimated Price
55 lbs/ft^3	5,000 tons	50' x 120'	Double conc.	$570,000
50 lbs/ft^3	15,000 tons	70' x 220'	Double conc.	$1,100,000

1/ The Richardson Rapid System, Process Plant Construction and Estimating Standards; Richardson Engineering Services, Inc., 1977-78 edition.

Using an estimate of six tons of coal used an hour, then a thirty day stockpile of coal based on twenty hours per day load requires a storage capacity of 3,600 tons. An exponential scale factor is calculated from the information in Table II-9.

$$\text{exponential} = \ln \frac{570}{1{,}100} \Big/ \ln \frac{5{,}000}{15{,}000} = .598 \text{ or approximately } .6$$

To estimate the costs of a silo capable of storing 3,600 tons of material the .6 scale factor is used.

$$\frac{3{,}600}{5{,}000}^{.6} \times \$570{,}000 = \$468{,}000 \text{ base silo cost}$$

Excluded from this base silo cost is the cost of pilings, foundations, weather protection, excavation and backfill. These are expected to add $50,000 onto the silo costs. However the costs of the pilings and foundation can vary significantly depending on the soil, seismic and wind conditions. This variability is left out of the present analysis.

Another factor that can affect silo costs is the cost of fire safeguards. This may include temperature detectors for hot spots, methane monitors, a CO_2 flood system and a ventilation system that can be made airtight. These safeguards along with silo adjustments to allow for an internal shelf and the applicable reclaim equipment are roughly estimated at $50,000.

The cost of an enclosed continuous bucket chain driven bucket elevator and storage tripper is estimated from Richardson[1/] at $30,000. The total cost of the silo storage system is estimated at $468 + 50 + 50 + 30 = $598,000. The high cost case for coal handling has a total cost of $897,000.

1/ op. cit.

FIGURE II-4

COAL-HANDLING EQUIPMENT SUITABLE FOR RAIL-CAR DELIVERY
(Approximate Capacity of Silo shown)

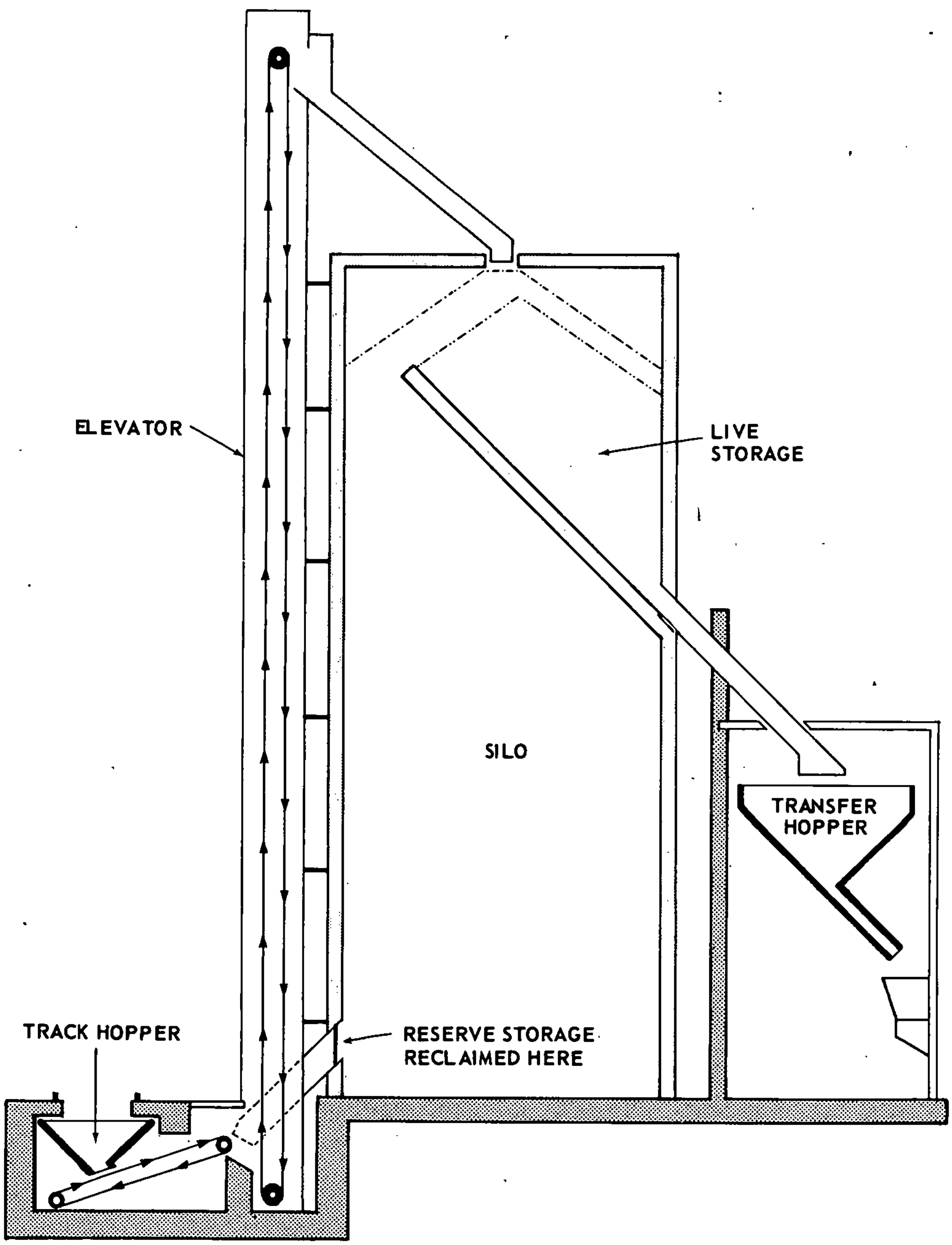


TABLE II-10

COAL HANDLING CAPITAL COSTS ($ thousands of 1977 dollars)

	Low Cost	Medium Cost	High Cost
Unloading -	61	61	61
Storage	168	208	598
Reclaim	127	167	127
Stockpile	111	111	111
TOTAL	467	547	897

iv) Operating and Maintenance Costs

The annual cost of supplies has been estimated by vendors as two percent of the basic equipment costs. Maintenance costs were estimated at six percent of installed equipment costs. Labor requirements for operation have been estimated by determining the hours of operation of the system during unloading and routine operations, and the personnel requirements for these operations.

Operation & Maintenance		
supplies = .02 x 356,000	=	7,120
maintenance = .06 + 356,000	=	21,360
labor (4000 hr load factor)	=	36,000
TOTAL		64,480

The O&M costs were expected to increase in the medium and high cost cases but only moderately.

v) Adjustments for Plant Type

The cost of coal handling equipment is assumed to be the same for both new plants and existing plants converting from oil or gas. Each is assumed to require a completely new system. Even though the costs are the same for different plant types the estimated frequency of occurrence is not. An existing plant is expected to face unfavorable site constraints more frequently than will a new plant.

An existing plant currently using coal presents several additional dimensions. Since a coal handling system already exists they only need to expand their current facilities. However, this often doesn't result in a significant cost savings. The capital costs of coal handling were found to increase almost linearly with respect to the size of the steam system. This results from smaller systems using a more simplified and more labor intensive handling system than is common among larger plants. An expansion in capacity often results in a revamping of the entire coal handling system. This is less likely to be true among plants that are already very large coal users. An addition of 120 tons of coal per day to a paper plant already consuming 800 tons per day may need relatively minor modifications in their handling system, where a plant doubling their steam output may choose to install an entirely new system.

Another consideration for plants currently using coal is the net addition to steam capacity. If a plant installs a 100 MMBtu/hr boiler and retires a 50 MMBtu/hr boiler then the net addition is only 50 MMBtu/hr. The coal handling system then needs to be expanded to handle only half of the coal that the new boiler is consuming.[1/]

These factors were considered for the existing plants already using coal early in the project. It was found that

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1/ However, if the coal handling system was installed at the same time as the boiler being retired then it may also be near its replacement age.

little information was available on which to base any frequency estimates. A decision was made to assume that all existing plants install an entirely new coal system. This results is an upward bias for the coal handling costs, but the bias is probably slight due to the few industrial plants currently burning coal.

The coal handling costs for each plant type is presented in Table II-11.

TABLE II-11

COAL HANDLING COSTS BY PLANT TYPE

	New Plant		Existing Plants different technologies		Existing Plants same technologies	
	freq.	capital costs	freq.	capital costs	freq.	capital costs
low cost	.5	467	.3	467	.4	467
med. cost	.3	547	.3	547	.3	547
high cost	.2	897	.4	897	.3	897

An overall cost distribution is calculated by the same method used in building block B8.11. The final costs are:

C8.11 COAL HANDLING (thousands of 1977 dollars)

	freq.	capital cost	operating and maintenance
low cost	.4	467	65
medium cost	.3	547	70
high cost	.3	897	75

The operating and maintenance costs were calculated separately for each coal handling system in EEA (9). The 12 percent estimate that appears on the computer printout for C8.11 is arrived at as follows:

1/ EEA paper study, op. cit.

$$.4 \frac{65}{467} + .3 \frac{70}{547} + .3 \frac{75}{897} = .119$$

Recall from the discussion of building block A8.11, site preparation and powerhouse, that since most of the cost variation in the coal handling component the variation that occurs in coal handling was incorporated into the site preparation component.

d. Building Block D8.11
Environmental Control and Waste Removal

The costs in this building block result from the particulate and SO_2 removal required by our environmental assumptions. This building block includes the costs of ash collection and disposal as well as the scrubber sludge disposal.

To meet the base case environmental assumptions of 80 percent sulphur removal and a particulate standard of .03 lbs/MMBtu input,[1/] all coal boilers were equipped with a scrubber and fabric filter. Two scrubbing systems were analyzed:[2/]

- a self contained, solid waste unit (SCSW) using either a spray tower or packed bed type of scrubber; with a lime/limestone or dual alkali system for SO_2 removal.

- a self contained, liquid waste stream unit (SCLW) using a spray tower or packed bed scrubber using sodium carbonate as the scrubbing solution.

The self contained, solid waste (SCSW) scrubber has much higher capital costs than the self contained liquid waste (SCLW) scrubber, but its operating costs are lower. As a result the SCSW scrubber is cheaper at larger sizes and load factors. Currently a SCLW scrubber is cheaper in terms of its annual cost for a 100 MMBtu/hr boiler at load factors up to 8000 hours and for 250 MMBtu/hr boiler at load factors up to 6000 hours. See Figures II-5 and II-6.

1/ See Chapter V, Volume I, book 2.

2/ Guide Book to the Applicability of Flue Gas Desulfurization for Industrial Coal-Fired Boilers, prepared for the Federal Energy Administration, by Energy and Environmental Analysis, Inc. November 3, 1977.

FIGURE II-5

COMPARISON OF ANNUAL SCRUBBING COST/TON OF COAL VS. OPERATING HOURS

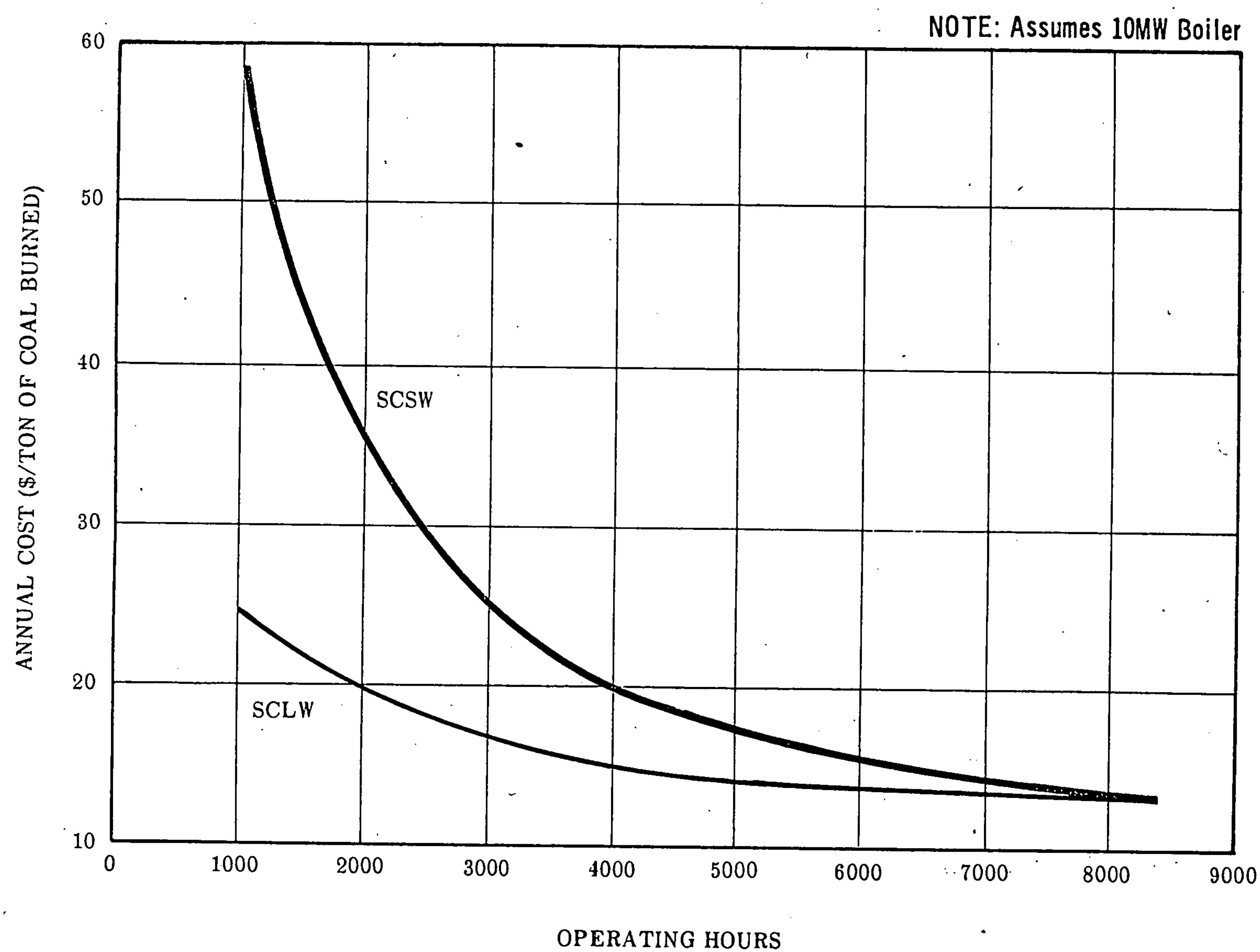
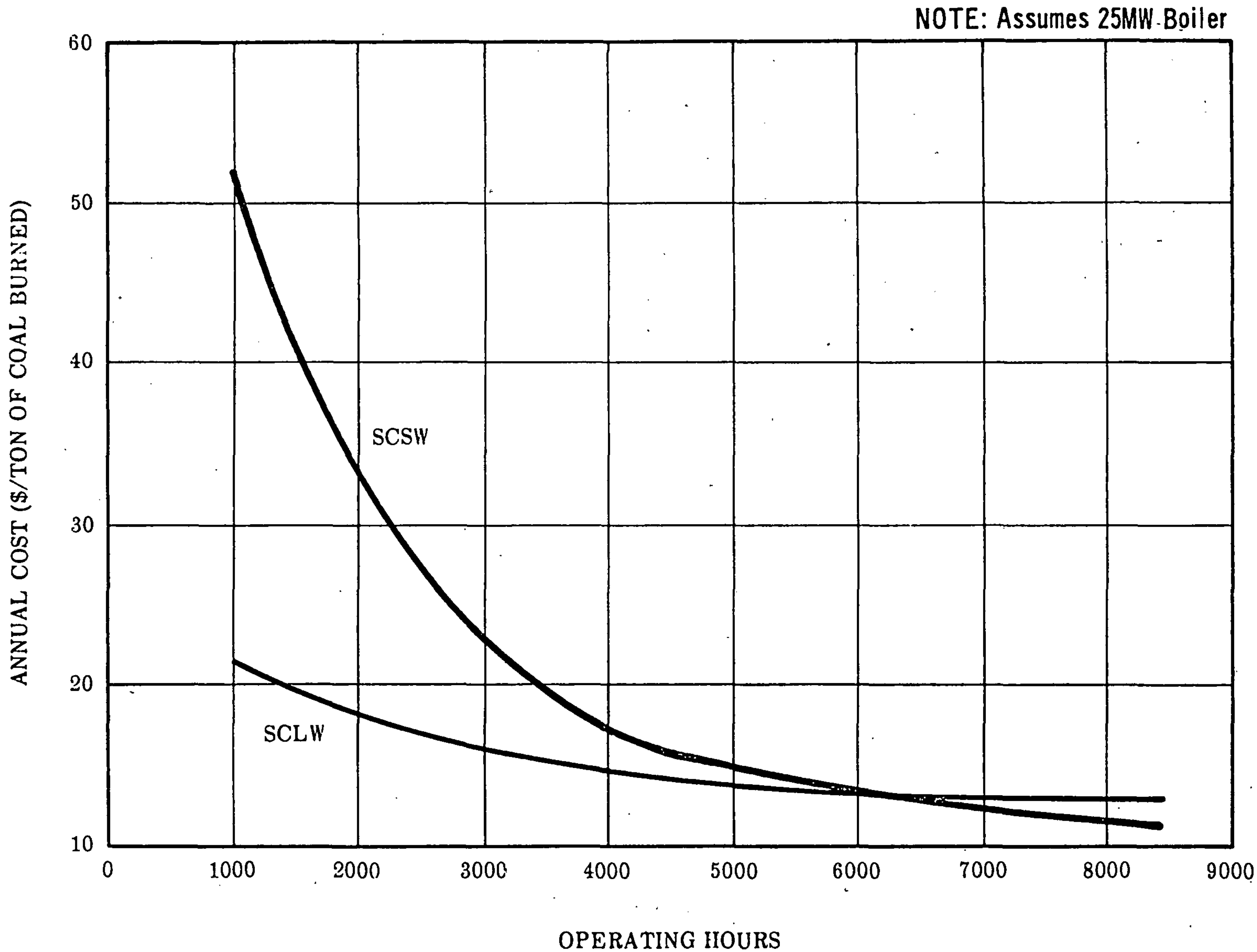


FIGURE II-6

COMPARISON OF ANNUAL SCRUBBING COST/TON OF COAL VS. OPERATING HOURS



The higher operating costs of the SCLW system are the result from the use of more expensive chemicals such as sodium carbonate or sodium hydroxide, and the need to dispose of a liquid waste stream high in dissolved solids. The disposal of this waste steam can pose significant problems at many plants.

The scrubbing system assumed in this analysis is the self contained, solid waste system for all sizes and load factors. Two factors contributed to this decisions. One, it is likely that new environmental regulations will be imposed on the dumping of liquid wastes from the SCLW system. The additional treatment required for the removal of dissolved solids from the liquid waste stream greatly increases operating expenses to the extent of making the SCLW system uneconomic. Two: currently ISTUM only has operating and maintenance costs varying with respect to different load factors. The capital costs are assumed constant across different load factors. The incorporation of a the SCLW scrubbing system at low load factors and the SCSW system at high load factors would have required significant programming changes to allow for capital costs to be a function of load factor.

One cost factor that was ignored in this analysis is that some industries produce an alkaline waste stream as a by-product of their production process which can be used as the reactive agent in the scrubber. This waste stream scrubbing system is similar to the SCLW system except that the source of the alkaline chemical is a plant by-product. This can result in substantial cost savings over either the SCSW or SCLW systems. The availability of suitable waste streams is limited to relatively few industries, notably the iron and steel industry, petroleum refining industry and the paper industry; and only a limited subset of plants in these industries have an adequate waste stream. Still, where available, the existence of a suitable waste stream can result in scrubbing costs that are one fourth of the standard SCSW system. This greatly improves the relative economics of coal usage with SO_2 removal for those plants.

The scrubber cost estimates are derived from the Guidebook to the Applicability of Flue Gas Desulfurization, prepared by Energy and Environmental Analysis.[1/] The Guidebook surveyed FGD systems on 94 coal fired boilers. This information was supplemented by vendor quotations on FGD equipment.

The costs of a self contained solid waste stream scrubber is estimated at $1,500,000.[2/] The cost of particulate control was provided by the Industrial Gas Cleaning Institute and is estimated at $550,000. The capital costs do not vary significantly with coal type i.e., different sulfur and ash contents; however operating costs do. This dimension was lost in ISTUM since the operating and maintenance costs are presently expressed as a percentage of capital costs.

The costs of ash collection and removal are based on two EEA Reports.[3/] In our estimates it is assumed that the ash is disposed of with the scrubber sludge. The ash handling system involves one or more collection points, hoppers, conveying lines, blowers or pumps depending on whether the system is pneumatic or hydraulic, and silos or storage bins. The estimated capital cost is $290,000.

1/ Ibid.

2/ Ibid.

3/ op. cit. "Industrial Boiler Study".
op. cit. "Paper Study".

The total capital cost in thousands of 1977 dollars for environmental control and waste removal is:

lime/limestone or dual alkali scrubber -	$1,500
fabric filter -	550
bottom and fly ash collection -	290
TOTAL -	$2,340

The dimensions of variability that exist in this component are primarily site dependent, and largely related to the amount of space available. The space limitations can require more of the scrubber system to be field erected. Shop fabricated modules may not meet the plant layout or design requirements. This can greatly increase the costs of installing the equipment. To help reduce the amount of site related variability among the building blocks this installation variability was incorporated into building block A8.11. Additional information is presented in the earlier discussion of building block A8.11.

The capital cost for the scrubber and ash collection system is assumed constant for the different plant types. Each plant, new or existing, would require a completely new system. There are different frequencies of occurences for the cost cases for each plant type. This was taken into consideration when arriving at the frequencies for building block A8.11.

The estimated operating costs include the costs of electricity, chemicals, water, maintenance, labor and waste removal. The operating costs for the scrubber are estimated at:

electricity	7.90	dollars per hour of operation
chemicals	11.00	
water	.77	
labor	8.00	
waste disposal	10.50	
total	38.17	dollars per hour of operation.

In addition a fixed fee for maintenance of $46,000 is assumed. Then for 4000 hours of operation the scrubber operating costs are $200,000. The operating costs of the fabric filter and the bottom ash collection equipment are estimated at $30,000. The total operating and maintenance cost estimate is $230,000 or roughly ten percent of the capital cost.

These operating costs are subject to a high degree of variability. The characteristics of the coal can affect the operating costs. A low sulfur content can reduce the amount of reagent chemicals required and the amount of scrubber sludge produced. The operating costs are also sensitive to the ash content of the coal but not to as high a degree. Another variable factor is the cost of waste disposal. The costs of waste removal can be reduced if the plant site is suitable for ponding of the sludge. Where on-site disposal is not feasible the costs of waste removal depend upon the hauling costs. These are site specific and depend upon the distance the sludge must be moved.

e. Building Block E8.11
Feedwater System and Utilities

This building block includes the costs of the field electrical system and the feedwater treatment and hookups.

The electrical power is assumed to be provided by a utility. However numerous transformers, switching gears and control station are needed to operate the boiler, pollution equipment, fuel handling systems and other plant equipment. These electrical equipment costs are assumed not to vary from plant to plant. The cost variation in this component is the result of different requirements for boiler feedwater treatment.

Feedwater impurities can cause many boiler problems. External treatment of the water is required when one or more of the feedwater impurities is too high to be tolerated by the boiler system. Often the feedwater must be filtered, softened and demineralized. Naturally occurring water contains suspended solids which must be removed before the water is used. These solids are removed in a filtration process that utilizes the addition of aluminum sulfate. The addition of alum to the water forms a floc around the suspended material. It is this floc which settles and is consequently filtered. The softening and demineralization processes are carried out through ion exchange. In all cases, a condensate return system with 30 percent make up water is assumed. Most steam systems now being built include condensate return.

i) Best Case - low cost case

The water available through the municipal system is used. The water is "good" water in that the only treatment required is deareation. For industrial boilers not generating electricity some municipal water can be used without major treatment. The costs reflect the electrical system, the deareator, the pumping equipment and the condensation system.

ii) Medium cost case

The water available requires deareation, softening and the removal of suspended solids. All other elements are the same as in the best case.

iii) High cost case

Significant water treatment is required. In addition to the softening and removal of suspended particles, extensive demineralization is needed. Demineralization is much more expensive than softening or filtration. Other elements are the same as the best case.

iv) Operating costs

The operating costs include the chemicals required for feedwater treatment, the cost of the water, general maintenance costs and the costs of monitoring the system.

v) Final cost distribution

No cost differences are assumed for different plant types. This implies that new systems are assumed to be required for every boiler addition. It is rare that excess capacity exists in feedwater systems.

Building Block D8.11 Feedwater System and Utilities
(thousands of 1977 dollars)

	frequency	capital costs	operating costs
low cost	.2	210	14
medium cost	.5	260	20
high cost	.3	660	40

Information recently made available indicates that our frequencies should probably be more heavily weighted to the high cost end. This change will be made in subsequent model runs.

f. Building Block H8.11

Indirect Capital Costs

In addition to the direct capital costs, other indirect capital costs are included in conventional industry cost estimation. These costs include items like engineering, taxes, freight, insurance and a contingency factor. They are usually estimated as a percent of direct capital costs.

Indirect Cost	Cost Range
engineering and design	10% - 15%
taxes	2% - 4%
insurance	1% - 3%
freight	1% - 3%
contingency	10% - 30%
startup costs	5% - 10%
	30% - 65%

The startup costs reflect the initial stockpiling of required materials[1/] and a shakedown period where operating costs are above normal. These costs are included in the capital cost estimates since they are only incurred once and are not part of regular operation.

The frequency estimates were subjectively determined utilizing past experience and engineering judgement.

H8.11 Indirect Capital Costs

frequency	multiplier
.55	1.30
.35	1.40
.10	1.5
.00	1.65

1/ Excluding costs of accumulating the coal stockpile.

Note that this component doesn't reflect the largest cost overrun possible, only those contingencies that can be expected to be incorporated into the cost estimatation procedure upon which the decision to choose one technology over another is made. Actual cost overruns incurred during construction may be much greater due to unforseen circumstance.

g. Building Block I8.11
Regional Indices

Regional adjustment factors were calculated to represent cost variation as a result of differing labor and material costs in different geographical areas. These regional factors can impact on the comparative economics of energy technologies. For example a technology which has high capital and operating costs but a low annual fuel cost when compared to a technology which has a low capital cost and a high fuel cost, will have more favorable economics in a region where labor and material costs are cheaper.

A composite regional index was constructed from the Building Cost Modifier.[1/] Labor rates were considered along with key materials like steel structures, concrete and equipment.

Regional Indices for DOE Demand Regions

South Atlantic	.87
Middle Atlantic	.94
South West	.94
New England	.96
Central	.97
Midwest	1.00
Northwest	1.05
New York/New Jersey	1.07
West	1.11

The frequency estimates were calculated from the current energy use in each region and their estimated growth rates provided by Data Resources Incorporated. Of course these regional indices are in fact region-wide averages. The use of a continuous rather than a discrete frequency distribution in ISTUM adjusts for this as well.

1/ Building Cost Modifier, Publication 10, No. 5, September thru October 1977, Boeckk Publications.

h. Calculation of Size Coefficients for Conventional Coal Steam I.D. 8.11

The original cost data for the conventional coal, oil and gas steam technologies were collected for units sized at 100,000 lbs/hr and 250,000 lbs/hr steam. The units that were deemed desirable for the ISTUM model were in terms of service demand or Btu's delivered to the work piece. A conversion factor of 1200 Btu's for each pound of steam was used. The block coefficients that appear on the technology specifications (green sheets) are used to adjust the cost data originally collected for a 100,000 lbs/hr system to costs relevant for a 100 MMBtu/hr service demand unit. A linear scale factor of 100 MMBtu/120 MMBtu or .83 is used as the block coefficient. For this small a range it was felt that a linear scale factor was a good approximation.

The block coefficient should differ from one only for applications involving steam. For all non-boiler applications the block coefficients should equal one.[1/] The use of the block coefficient is not generally necessary; it was incorporated only to help the data base managers identify the appropriate steam conversion units.

The calculated costs for the two steam system sizes, 120 and 300 MMBtu/hr are presented in Table II-12. The .83 conversion factor is used to adjust these costs to 100 MMBtu/hr and 250 MMBtu/hr. The size coefficient for scaling the costs in building block A8.11 to costs appropriate for a 250 MMBtu/hr unit is calculated from the cost values in Table II-12 as follows:

1/ Medium Btu gas is an exception to this. The gas producing building blocks should have a block coefficient value of two.

$$.5\left(\frac{1190}{541}\right) + .4\left(\frac{1790}{823}\right) + .1\left(\frac{3600}{1761}\right) = 2.17$$

Thus a scale up factor of 2.17 is used. The size coefficients for the other building blocks can be calculated similarly. The calculations of site costs for a 250 MMBtu/hr unit is then:

(A8.11)

$$\begin{bmatrix} 541 \\ 823 \\ 1761 \end{bmatrix} \times .83 \times 2.17 = \begin{bmatrix} 974 \\ 1482 \\ 3171 \end{bmatrix}$$

The work on the demand side of the data base indicated that the appropriate segmentation of the steam service sector requires two boiler sizes, 50 MMBtu/hr and 250 MMBtu/hr. To calculate the small size (50 MMBtu/hr) coefficient an exponential scale factor was used. For building block A8.11 the exponential scaler is calculated as follows:

$$\left(\frac{250}{100}\right)^{x} = \left(\frac{2.17}{1.00}\right)\left(\frac{.83}{.83}\right)$$

$$x = \frac{\ln(2.17)}{\ln(2.5)} = .84$$

The small size (50 MMBtu/hr) coefficient for A8.11 is then:

$$\left(\frac{50}{100}\right)^{.84} = .558$$

TABLE II-12

CONVENTIONAL COAL STEAM COSTS - TECHNOLOGY 8.11

(costs in thousands of 1977 dollars)

Building Blocks	frequency	100,000 lbs/hr (120 MMBtu/hr) Capital	Operating	250,000 lbs/hr (300 MMBtu/hr) Capital	Operating
A8.11					
low cost	.50	541	16	1,190	35
medium cost	.40	823	25	1,790	54
high cost	.10	1,761	50	3,600	108
B8.11					
low cost	.35	1,500	172	2,950	340
medium cost	.55	2,100	240	3,830	440
high cost	.10	2,520	280	4,300	495
C8.11					
low cost	1	467	46	935	93
medium cost	--	--		--	
high cost	--	--		--	
D8.11					
low cost	1	2,340	234	4,480	448
medium cost	--	--		--	
high cost	--	--		--	
E8.11					
low cost	.20	210	15	380	26
medium cost	.50	260	18	490	34
high cost	.30	660	46	1,200	84
H8.11					
low cost	.55	1.3	--	1.3	--
to	.35	1.4	--	1.4	--
	.10	1.5	--	1.5	--
high	.00	1.65	--	1.65	--
I8.11					
low cost	.40	.87	--	.87	--
to	.40	.97	--	.97	--
	.20	1.07	--	1.07	--
high	.00	1.25	--	1.25	--

2. Conventional Natural Gas and Oil in the Steam Service Sector

The derivation of the conventional natural gas and oil costs are presented together for this steam service sector. The cost components for the two technologies are very similar. This often resulted in parallel estimation procedures for these two technologies.

DISCUSSION OF BUILDING BLOCKS

a. Building Block A8.11
Site Preparation and Power House

This building block is used to estimate the site preparation and power house costs for an oil or gas boiler. The same considerations involved in the estimation of the site preparation and power house costs for a conventional coal system are also applicable to an oil or gas steam system.

The building block derived from the site preparation and power house costs for conventional coal steam is adjusted via the block coefficient and size coefficient to represent the costs for oil and natural gas boilers. The calculations of these coefficients are presented at the end of this section.

As in coal, this component includes the cost of constructing the power house and of all the necessary land preparation. A gas or oil fired steam system requires much less land than does a coal system. The oil and gas land requirements were found to be approximately one fifth of the coal land requirements. The costs of constructing the power house are also lower than those for a coal boiler. Oil and gas boilers are lighter and smaller. There is no coal bunker, so the steel support structure is not nearly as extensive and the power house foundation requirements are more moderate for an oil or gas boiler.

The permit costs for an oil or gas fired facility are about half as expensive as for coal. The burning of oil or gas does not have as many undesirable environmental effects as a coal fired system does.

The definitions of the low, medium and high cost subcases are the same as those for coal. The same calculations that were made for coal in A8.11 to adjust for the site related interdependencies among building blocks were also made for oil and gas. The overall site preparation and power house costs were found to be between 50 percent and 60 percent of the calculated coal costs.

Gas or Oil Steam System Site Preparation and
Power House Costs
120 MMBtu/hr unit
(thousands of 1977 Dollars)

	frequency	capital	maintenance
low cost	.5	310	10
medium cost	.4	490	14
high cost	.1	920	27

b. Building Block B8.11
Boiler Equipment

The estimated boiler equipment costs for oil and gas boilers are considerably less than those for a coal boiler. Their smaller size and weight allows for the complete boiler to be transported by rail. This facilitates shop fabrication of the boiler. A complete oil or gas boiler can then be shipped as a package to the installation site. This results in a considerable cost savings. The low, medium and high cost subcases are defined the same as those for the conventional coal boiler. The demand for redundant equipment is the source of the cost variation.

Gas or Oil Boiler Equipment Costs for a
120 MMBtu/hr Unit
(thousands of 1977 $'s)

	capital	operating
low cost case - 1 boiler	555	63
medium cost case - 2 boilers	721	83
high cost case - 3 boilers	888	100

c. Building Block C8.11
Fuel Handling

The fuel handling costs for oil and gas are the result of pumps, piping and storage. Since natural gas supplies are uncertain and many plants are subject to interruptable service it is assumed that all gas boilers are capable of oil firing and have a full complement of oil storage and handling facilities.

A three week supply of oil is assumed to be stored. A boiler supplying 120 MMBtu/hr steam, assuming an oil with a Btu content of 6.3 MMBtu per barrel, consumes 23 barrels of oil per hour. A three week supply based on a 7000 hr. load factor is 9,700 barrels of oil. The cost of an A.P.I. floating roof storage tank with a 10,000 barrel capacity is calculated from Richardson[1/] at $90,000 without foundation. The appropriate foundation was felt to add $10,000 on to the tank cost.

The cost of accumulating a three week oil stockpile assuming an oil cost of $17.00 per barrel is $165,000. Other fuel handling requirements are an unloading area, piping, pumps and a heater to maintain the viscosity of the oil. In addition, an earthen dike must be built around the tank to contain any oil released through rupture or leakage.

Fuel Handling Costs

storage tank	$100,000
fuel stockpile	$165,000
other equipment	$ 30,000
TOTAL	$295,000

The storage and handling system for oil does not exhibit the same degree of cost variability as does a coal handling system. The cost variability that does exist is primarily the result of difficult site conditions. For example, unstable soil conditions may require a more substantial foundation for the storage tank or the design of the land may require the storage tank to be placed at a greater than optimal distance from the plant increasing piping and pump costs. Usually the storage tank is required to be placed at some distance away from all buildings due to the danger from fire. Distances of up to 50 yards have been required in some areas. There are additional restrictions placed on the location of the fuel unloading area, depending on the size of the tank and the amount of fuel unloaded. A certain minimum distance must be kept between the tank and the unloading facility.

1/ Richardson op. cit.

Since the primary source of cost variablity is the result of site factors, this variability is incorporated into the site preparation component. The same procedure was used in the conventional coal steam site preparation building block A8.11. Please refer to that section for a more complete explanation.

In general the fuels handling and storage costs for oil were found to be approximately 60 percent of the coal handling and storage costs. The operating and maintenance costs were calculated to be 12 percent of the capital costs.

d. Building Block D8.11
Environmental Controls and Waste Removal

Natural gas is a clean burning fuel and is not subject to any environmental regulations. Oil fired boilers were required to have an electrostatic precipitator for particulate control in the base case. A precipitator is used instead of a fabric filter since the flue gas resulting from oil combustion contains "sticky" particulates which can clog or blind the filter.

The estimated capital cost of a precipitator for a 120 MMBtu/hr oil boiler is $112,000[1/]. Operating cost are estimated at $10,000 per year and include the costs of ash disposal.

e. Building Block E8.11
Feedwater System and Utilities

The feedwater treatment system is assumed to be the same as that required for a coal boiler system. The cost differential between oil or gas boilers and conventional coal is the

1/ "Industrial Boiler Study" prepared for the Federal Energy Administration, by Energy and Environmental Analysis, Inc. December 1977.

result of a smaller electricity requirement. The fuel handling and environmental system for oil requires fewer transformers, switching gears and other electrical equipment reducing the cost of the auxiliary utilities.

For a 120 MMBtu/hr system these costs are estimated at:

Feedwater System and Auxilaries
(thousands of 1977 $'s)

	frequency	capital cost	operating cost
low cost	.20	170	11
medium cost	.55	220	15
high cost	.25	560	40

f. Building Blocks H8.11 and I8.11

These two building blocks represent the indirect capital costs and the installation indices, respectively. The explanation of these costs contained in the conventional coal section are directly applicable here. Please refer to that section for a complete presentation.

g. Calculation of Size Coefficients for Conventional Oil and Gas Steam -- I.D.'s 8.21 and 8.31

The calculated costs for conventional oil fired steam appear in Table II-13. The costs for conventional gas are the same, except for slightly lower site preparation and power house costs; and there are no environmental costs.

The same cost components that are relevent for coal steam systems are also relevent for oil and gas systems. This allows us to express the oil and gas technology costs by using the building blocks developed for the conventional coal technology 8.11. The block coefficients in Table II-14 adjust the costs in the relevent building block to reflect the costs of the gas or oil unit at 100 MMBtu/hr. These block coefficients are calculated from the values in Table II-13 and relevant coal building blocks. For example, the block coefficient in the technology specification appropriate for A8.11 is calculated by:

$$.83\left[.5\ \frac{310}{541} + .4\ \frac{490}{823} + .1\ \frac{920}{1761}\right] = .478$$

The calculations inside the square brackets determines the scaler appropriate for reducing the costs in building block A8.11 to costs relevent for an oil steam system sized at 120 MMBtu/hr. The .83 is a linear scaler used to adjust costs from 120 MMBtu/hr to a 100 MMBtu/hr sized unit[1/].

The oil and natural gas size coefficients are calculated in the same manner as were the conventional coal size coefficients. The size coefficients on A8.11 for the 250 MMBtu/hr sized oil steam system were calculated directly from the costs in Table II-13:

1/ The .83 scaler is derived in the explanation of size coefficients for conventional coal steam (ID 8.11).

TABLE II-13

CONVENTIONAL OIL STEAM COSTS - TECHNOLOGY 8.21

(costs in thousands of 1977 dollars)

Building Blocks	frequency	100,000 lbs/hr (120 MMBtu/hr) Capital	Operating	250,000 lbs/hr (300 MMBtu/hr) Capital	Operating
Site Prep.					
low cost	.50	310	10	690	20
medium cost	.40	490	14	990	
high cost	.10	920	27	1,600	
Boiler Equipment					
low cost	.35	555	64	1,280	340
medium cost	.55	721	80	1,670	440
high cost	.10	888	162	2,050	495
Fuel handling					
low cost	1	295	28	530	50
medium cost	--	--		--	
high cost	--	--		--	
Environmental					
low cost	1	112	11	225	22
medium cost	--	--		--	
high cost	--	--		--	
Feedwater and Auxiliaries					
low cost	.20	170	11	335	23
medium cost	.50	220	15	440	30
high cost	.30	560	40	1,130	78
Indirect Capital Costs					
low cost	.55	1.3	--	1.3	--
to	.35	1.4	--	1.4	--
	.10	1.5	--	1.5	--
high	.00	1.65	--	1.65	--
Installation Indices					
low cost	.40	.87	--	.87	--
to	.40	.97	--	.97	--
	.20	1.07	--	1.07	--
high	.00	1.25	--	1.25	--

TABLE II-14

Gas and Oil Building Block Coefficients

Conventional Natural Gas

Tech I.D. - 8.31

Building Block	Block Coeff.	Size Coeff. (50)	Size Coeff. (250)
A8.11	0.46	0.57	2.10
B8.11	0.29	0.53	2.30
C8.11	0.50	0.64	1.80
D8.11	0	0	0
E8.11	0.70	0.59	2.00
H8.11	1.00	1.00	1.00
I8.11	1.00	1.00	1.00

Conventional Oil

Tech I.D. - 8.21

Building Block	Block Coeff.	Size Coeff. (50)	Size Coeff. (250)
A8.11	0.48	0.57	2.08
B8.11	0.29	0.53	2.30
C8.11	0.50	0.64	1.80
D8.11	0.04	0.59	1.98
E8.11	0.70	0.59	2.00
H8.11	1.00	1.00	1.00
I8.11	1.00	1.00	1.00

$$.5\ \frac{690}{310} + .4\ \frac{990}{490} + .1\ \frac{1600}{920} = 2.10$$

The coefficients on A8.11 for the smaller size oil steam system are calculated by a two step procedure where an exponential scaler is first calculated to capture any economies of scale present. Then this exponential factor is used to determine 50 MMBtu/hr size coefficient:

$$\frac{250}{100}^{x} = \frac{2.10}{1.00}\ \frac{.46}{.46}$$

$$x = .809$$

$$\text{Then:}\quad \frac{50}{100}^{.81} = .57$$

This same procedure can be used to determine the block and size coefficients for all the building blocks specified by the conventional oil and gas technologies.

3. Technology 8.41 - Black Liquor and Wood Boilers

The capital costs for this technology were assumed to be the same as those for conventional coal, except for fuels handling costs which were assumed to be one half the conventional coal handling costs (building block C8.11). Particulate control was required, but not SO_2 removal.

The most important specification for this technology is the determination of its potential market. Since it uses a waste by-product it has virtually no fuel cost. This results in such a low cost per MMBtu steam output that the technology will capture virtually any market that it is allowed to compete for. The important parameters are the industries in which the technology is allowed to compete and the maximum fraction that it is assigned.

It was found that only the paper industry has sufficient quantities of black liquor or wood and a large enough steam demand to allow this technology to have a significant impact. Within the paper industry it was found that the amount of black liquor and wood byproducts produced in 1974 could meet forty percent of the industries steam demand for that year[1/]. This fraction is expected to remain fairly stable over the next decade. Based on this information a maximum fraction of .40 was assigned to black liquor and wood boilers.

1/ EEA "Paper Study" op. cit.

4. Conventional Technologies in the Space Heat Service Sector

Four conventional technologies compete in the space heat service sector. Three of them, conventional gas, oil and coal are steam producing technologies. The fourth technology is an electric heat pump.

Boiler systems designed primarily for space heating applications are usually smaller and operate at lower pressures and temperatures than do boilers designed to produce steam for process uses. The costs calculated for the conventional technologies in the steam service sector are also applicable in the space heat service sector, even though boilers that operate at lower temperatures and pressures are less expensive in terms of pounds of steam produced. In ISTUM all units are sized by service demand or MMBtu's of steam produced. Lower boiler pressures and temperatures reduce the Btu content of the steam requiring more pounds of steam to meet a specific service demand. These are offsetting cost factors. The boiler equipment is less expensive per pound of steam but more steam is required.

The size coefficients for the boiler technologies in the space heat service sector were calculated using the same exponential scalers derived for each technology in the steam service sector.

The costs for the one non-boiler conventional technology in the space heat service sector, electric heat pumps, were obtained from carrier heat pump representatives.

C. Non-Boiler Conventional Technologies

There proved to be little available information in the published literature on the costs relating to the non-boiler applications of natural gas, oil and coal. The source of the ISTUM cost estimates were two EEA studies.[1,2] In the development of a forthcoming industrial coal conversion study[3] five months were available to investigate the costs of these non-boiler applications. The wide diversity of non-boiler applications, along with the absence of any significant number of published cost studies resulted in cruder cost estimates for these technologies.

The cost information available on the non-boiler applications did not lend itself to as extensive a cost component breakdown as was available for the boiler applications. Often the costs available were for the entire plant and estimates had to be made concerning the proportion of the total plant cost that was represented by the energy producing equipment.

Non-boiler energy applications are represented by service sectors:

1/ "The Potential for Natural Gas Substitution in Selected Industries", Prepared for the U.S. Department of Commerce, by Energy and Environmental Analysis, Inc., December 20, 1977.

2/ "Industrial Coal Conversion Model", for the Office of Policy and Evaluation, DOE, by Energy and Environmental Analysis, Inc., in progress.

3/ Ibid.

2 Direct Heat - (Intermediate)
3 Direct Heat - (Dirty)
4 Indirect Heat (coal capable)
13 Indirect Heat (coal incapable)
14 Calcining
15 Glass Melting
16 Brick Firing
17 Iron Making
19 Steel Reheating

The approach used in each non-boiler service sector was to pick one application that seemed to be the most representative of all the applications in that service sector. In service sectors where two sizes were needed to portray it, two applications, one for the small size and one for the large size were chosen. Most of the service sectors are narrowly enough defined for this assumption not to present severe difficulties. The exceptions are the direct heat service sectors which are the most diverse and consequently the worst specified by this approach. It would be helpful to further disaggregate these service sectors in the future.

1. Building Blocks Used to Specify Natural Gas Non-Boiler Technologies:

a. Building Blocks A8.3XX[1/] and F8.3XX-Primary System

For each natural gas application in each service sector a building block labeled primary system was estimated. In service sectors with one size only the A8.3XX block is used. Where another size and application is used an F8.3XX building block is also used. For example in service 17 ironmaking the technology specification is:

Tech I.D. 8.317

Block I.D.	Block Coeff.	Size Coeff.	Size Coeff.
A8.317	1.0	1.0	0.0
F8.317	1.0	0.0	1.0
C8.216	1.0	.18	6.65
H8.11	1.0	1.0	1.0
I8.11	1.0	1.0	1.0

This building block A8.317 represents the costs associated with a blast furnace stove sized at 1.6 MMBtu/hr and F8.317 comprises the costs for a blast furnace hydrocarbon injection system sized at 133 MMBtu/hr. These primarily system building blocks include the costs of the energy equipment, foundation, supports, stack if required and any other costs associated with the housing of the energy equipment. Fuel handling and pollution control costs are handled separately. The costs in these building blocks were taken directly from the forthcoming industrial coal conversion study by EEA.[2/]

1/ XX represents any non-boiler service sector number.

2/ EEA "Coal Conversion Study", op. cit.

b. Building Block C8.316 - Fuel Handling

All natural gas technologies were required to be able to fire oil as a hedge against possible natural gas shortages. This building block represents the costs of a complete oil handling and storage system as outlined for technology 8.21, conventional oil steam. This building block was used in the specification of all the natural gas technologies.

c. Building Blocks H8.11-Indirect Capital Costs and I8.11-Regional Indices

These are multiplicative building blocks. They are used in all the natural gas technologies. Their derivation is presented in conjunction with the discussion of technology 8.11 conventional coal steam.

2. Building Blocks Used to Specify Oil Fired Non-Boiler Technologies

a. Building Blocks A8.3XX and F8.3XX[1/] Primary System

The primary system building blocks used to specify the natural gas technology in service sector XX was also used to specify the oil fired technology in that service sector. The costs for the use of oil in these applications were taken directly from the industrial coal conversion study by EEA[2/]. A scaler was calculated to adjust the natural gas costs to represent the costs of oil firing.

b. Building Block B1.14 Particulate Control

The costs in this building block represent the costs of an electrostatic precipitator for particulate control.

c. Building Block 8.216-Fuel Handling

This building block was used to specify the costs of oil handling and storage for all the non-boiler oil technologies.

d. Building Blocks H8.11-Indirect Capital Costs and I8.11-Regional Indices

These building blocks appear in all oil technologies and are discussed with technology 8.11 conventional coal steam.

1/ XX represents any non-boiler service sector number.

2/ <u>Ibid</u>.

3. Building Blocks Used to Specify Conventional Coal Fired Non-Boiler Technologies

a. Building Blocks A8.3XX and F8.3XX

These primary system building blocks used to specify the natural gas technology in service sector XX were also used to specify the coal technology in the same service sector. The costs of coal firing in each service sector were taken directly from the industrial coal conversion model. A scaler was calculated to adjust the natural gas primary system costs up to those of the coal fired technology.

b. Building Block B8.116-Particulate Controls

This building block reflects the cost of a fabric filter for particulate control.

c. Building Block C8.116-Fuel Handling

This building block specifies the costs of coal handling and storage. It is used in the specification of every non-boiler coal technology.

d. Building Block D8.14-Sulfur Removal

This building block represents the costs of a scrubber and solid waste removal associated with the use of coal in the indirect heat service sector.

e. Building Block G5.12-Pulverizer

Some of the non-boiler coal technologies required pulverized coal. This building block specifies the capital costs associated with the pulverizer equipment.

f. Building Blocks H8.11-Indirect Capital Costs and I8.11-Regional Indices

These building blocks are included in every technology specification and are discussed in conjunction with technology 8.11 conventional coal steam.

4. Normalization of Non-Boiler Primary System Costs

The costs of the primary energy system of these non-tboilers technologies contain costs of some components that were not directly related to the type of fuel used or the specific energy technology used. For example, the application of direct heat to a solid material requires sophisticated equipment to pass the material through the furnace. A steel reheat furnace may use a water cooled conveyor to pass the steel through the furnace. Water is passed through the wheels of the conveyor to prevent them from heating up to the furnace temperature. The costs associated with this type of equipment are not directly attributable to the energy system. In an attempt to eliminate these non-energy related costs the original primary system costs were "normalized". The procedure was to relate all technology costs to the cost of the natural gas technology costs by specifying that every 100 MMBtu's of natural gas consumed and resulted in an equipment capital cost of $500,000. Once the natural gas costs were normalized, the cost of the oil technology was determined by maintaining the same cost differential between the oil and gas technologies that occurred in the original costs. The same procedure is used to specify coal costs. An example is worked out below.

Normalization Example:

In service sector #3, dirty direct heat, the original costs in the low cost case were:

natural gas	$299,000
oil	$350,000
coal	$404,000

The service demand size is 10 MMBtu/hr with an efficiency of .30. The natural gas consumption is 33.3 MMBtu/hr. The normalized natural gas cost is found by:

$$\frac{33.3\ \text{MMBtu}}{100\ \text{MMBtu}} = \frac{\text{normalized cost}}{\$500{,}000} \quad \text{or normalized cost} = \$167{,}000.$$

The costs of oil and coal in dirty direct heat are then:

($350,000) - $299,000) + $167,000 = $218,000 for oil, and
($404,000 - $299,000) + $167,000 = $272,000 for coal.

This maintains the same cost differentials between the natural gas, oil and coal technologies. This specifies the normalized costs for the best case of each technology. To normalize the costs for the medium cost and high cost cases, the percentage change from one cost case to another was maintained.

Tables II-15 through II-22 present the applications picked to portray each service sector, the original primary system costs obtained from the industrial coal conversion model[1/] and the normalized costs used in ISTUM. Any special assumptions required are also listed with these tables.

In general, the costs of these non-boiler applications represent one of the weakest data areas in the model. This will be one of the first areas to be improved in the next stage of model development.

1/ EEA "Coal conversion model," op. cit.

TABLE II-15

PRIMARY SYSTEM COSTS*

Service Sector #2, Direct Heat (Intermediate)

Two applications were used as representative of the intermediate direct heat service sector. The larger size represents metal heating and the costs are derived from the industrial coal conversion specifications for aluminum melting, holding and casting. The smaller size represents food drying and the costs for grain dryers were used.

Metal Heating: Size 50 MMBtu/hr, eff. .36

Original Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	3735	3735	4150
medium cost case	4150	4150	4611
high cost case	4565	4565	5072

Normalized Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	695	695	1110
medium cost case	772	772	1233
high cost case	849	849	1356

Food Drying: Size 10 MMBtu/hr, eff. 36

Original Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	41	66	N.A.
medium cost case	67	107	N.A.
high cost case	108	173	N.A.

No normalization procedure was required for food drying. Small food drying applications are not technically or economically feasible for coal firing.

* The primary system does not include fuel handling or pollution control equipment.

TABLE II-16

PRIMARY SYSTEM COSTS*

Service Sector #3, Direct Heat (Dirty)

The chosen representative dirty direct heat application is aluminum fabrication. Two sizes of this technology were used, 10 MMBtu/hr and 50 MMBtu/hr.

Metal Fabrication: Size 50 MMBtu/hr, eff. .30

Original Costs (thousands of $'s)	natural gas	oil	coal
low cost case	1,435	1,680	1,940
medium cost case	2,050	2,400	2,760
high cost case	3,278	3,840	4,430
Normalized Costs (thousands of $'s)			
low cost case	835	1,095	1,340
medium cost case	1,190	1,550	1,930
high cost case	1,905	2,485	3,095

Metal Fabrication: Size 10 MMBtu/hr, eff. .30

Original Costs (thousands of $'s)	natural gas	oil	coal
low cost case	299	350	404
medium cost case	427	500	577
high cost case	683	800	933
Normalized Costs (thousands of $'s)			
low cost case	167	218	272
medium cost case	238	311	388
high cost case	381	498	621

* Does not include fuel handling and pollution control cost.

TABLE II-17

PRIMARY SYSTEM COSTS*

Service Sector #4, Indirect Heat (Coal Capable)

The representative technology for this service sector is atmospheric distillation and catalytic reforming. Only one size was required.

Atmospheric Distillation and Catalytic Reforming:

Size 250 MMBtu/hr, efficiency .67

Original Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	4728	5033	15,250
medium cost case	4976	5297	16,050
high cost case	6635	7063	21,403

Normalized Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	1865	2170	12,387
medium cost case	1963	2284	13,037
high cost case	2617	3045	17,385

To derive the costs for service sector #13, indirect heat coal incapable, these same costs were repeated with the costs of conventional coal left out.

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* This cost does not include any fuel handling or environmental control costs.

TABLE II-18

PRIMARY SYSTEM COSTS*
Service Sector #14, Calcining

This service sector is involved with the production of cement, gypsum and concrete by the use of rotary kilns. The representative technology is the production of concrete. Only one size is used.

Calcining: Size 40 MMBtu/hr, effeciency .4
Original Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	560	560	560
medium cost case	590	590	590
high cost	787	787	787

Normalized Costs

	natural gas	oil	coal
low cost case	560	560	500
medium cost case	590	590	527
high cost case	787	787	703

* Does not include fuel handling or pollution control costs.

TABLE II-19

PRIMARY SYSTEM COSTS*

Service Sector #15 Glass Melting

This service sector is primarily made up of two energy applications, a unit melter and a regenerative furnace. A unit melter was used to represent the smaller size and the regenerative melter the larger size.

Regenerative Melter: Size 66.7 MMBtu/hr, eff. .33

Original Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	1,659	2,474	2,673
medium cost case	1,746	2,602	2,813
high cost case	2,328	3,465	3,755

Normalized Costs (thousands of $'s)

low cost case	630	1,445	1,644
medium cost case	663	1,520	1,730
high cost case	884	2,025	2,310

Unit Melter: Size 41.6 MMBtu/hr eff. .33

Original Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	1,659	1,659	1,746
medium cost case	1,746	1,746	1,838
high cost case	2,328	2,328	2,451

Normalize Costs (thousands of $'s)

low cost case	630	630	717
medium cost case	663	663	755
high cost case	884	884	1,007

* Does not include fuel handling or pollution control costs.

TABLE II-20

PRIMARY SYSTEM COSTS*

Service Sector #16, Brickfiring

The costs in this service sector represent regular brick firing as opposed to refractory brick firing since regular brick firing comprises 80 percent of the energy consumption in this service sector. Only one size is used.

Brickfiring: size 13.1 MMBtu/hr, eff. .31

Original Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	238	238	243
medium cost case	251	251	256
high cost case	334	334	341

Normalized Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	211	211	216
medium cost case	223	223	228
high cost case	297	297	304

* This cost does not include the cost of fuel handling or any environmental controls.

TABLE II-21

PRIMARY SYSTEM COSTS*

Service Sector #17, Ironmaking

Two energy applications are used to specify this service sector, blast furnace hydrocarbon injection is used to represent the large sizes and blast furnace stove is used to represent the small sizes.

Hydrocarbon Injection: size 133 MMBtu/hr, eff. 33

Original Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	9,542	9,542	10,260
medium cost case	10,004	10,004	10,000
high cost case	13,392	13,392	14,400

Normalized Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	2,015	2,015	2,733
medium cost case	2,121	2,121	2,877
high cost case	2,828	2,828	3,836

Blast Furnace Stove: size 1.6 MMBtu/hr eff. .33

Original Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	17,000	19,000	19,000
medium cost case	20,000	20,000	20,000
high cost case	26,660	26,660	26,660

Normalized Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	24	24	24
medium cost case	25	25	25
high cost case	33	33	33

* This cost does not include the cost of fuel handling or any environmental control.

TABLE II-22

PRIMARY SYSTEM COSTS*

Service Sector #19, Steel Reheat

Two applications are used to specify this service sector. A steel reheat furnace is the large application and annealing is used to represent the small application.

Steel Reheat Furnace: Size 60 MMBtu/hr, eff. .30

Original Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	4,811	4,811	4,960
medium cost case	6,014	6,014	6,200
high cost case	8,420	8,420	8,680

Normalized Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	1,000	1,000	1,149
medium cost case	1,250	1,250	1,436
high cost case	1,750	1,750	2,010

Annealing: size 3 MMBtu/hr, eff. .30

Original Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	2,813	2,813	2,870
medium cost case	4,018	4,018	4,100
high cost case	6,429	6,429	6,560

Normalized Costs (thousands of $'s)

	natural gas	oil	coal
low cost case	50	50	107
medium cost case	71	71	153
high cost case	114	114	245

Note: An additional conventional technology was added to this service sector. The captive gas technology 8.519 has the same capital costs as natural gas. Since it uses a process by-product there is little or no fuel cost. The maximum fraction was determined by the amount of captive gas available in the service sector.

* This cost does not include the cost of fuel handling or any environmental controls.

GENERAL INFORMATION FOR CONVENTIONAL TECHNOLOGIES

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TECH ID	TECHNOLOGY NAME	YEAR AVAIL	FUELS USED	FUEL SHARE (1ST FUEL)	FUEL EFFECIENCY COMB USTN	TRAN SMIS	FINL USE	SIZE RANGE (MMBTU/HR) LO	HI	LOAD RANGE (HRS/YR) LO	HI	MAXIMUM FRACTION INCRE MENTL	RETRO FIT	CONSE RVATN
5.114	NEW COAL DIRECT	1982	1	1.00	1.00	1.00	0.40	¯1	¯1	¯1	¯1	0.70	0.00	1.00
5.115	NEW COAL DIRECT	1982	1	1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.70	0.00	1.00
5.116	NEW COAL DIRECT	1980	1	1.00	1.00	1.00	0.31	¯1	¯1	¯1	¯1	0.70	0.00	1.00
5.117	NEW COAL DIRECT	1982	1	1.00	1.00	1.00	0.33	1	100	¯1	¯1	0.70	0.00	1.00
5.119	NEW COAL DIRECT	1982	1	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	0.70	0.00	1.00
5.12	NEW COAL DIRECT	1982	1	1.00	1.00	1.00	0.36	40	600	¯1	¯1	0.70	0.00	1.00
5.13	NEW COAL DIRECT	1982	1	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	0.70	0.00	1.00
5.14	NEW COAL IND	1981	1	1.00	1.00	1.00	0.67	¯1	¯1	¯1	¯1	0.70	0.00	1.00
8.11	NEW COAL BOILER	1920	1	1.00	1.00	1.00	0.82	¯1	¯1	¯1	¯1	0.70	0.00	1.00
8.112	NEW COAL	1920	1	1.00	1.00	1.00	0.82	¯1	¯1	¯1	¯1	0.70	0.00	1.00
8.21	NEW OIL	1960	2	1.00	1.00	1.00	0.82	0	99	¯1	¯1	1.00	0.00	1.00
8.212	NEW OIL	1960	2	1.00	1.00	1.00	0.82	0	150	¯1	¯1	1.00	0.00	1.00
8.214	NEW OIL DIR	1960	2	1.00	1.00	1.00	0.40	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.215	NEW OIL DIR	1960	2	1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.216	NEW OIL DIR	1960	2	1.00	1.00	1.00	0.31	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.217	NEW OIL	1960	2	1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.219	NEW OIL	1960	2	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.22	NEW DIR OIL	1960	2	1.00	1.00	1.00	0.36	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.23	NEW OIL DIRECT	1960	2	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.24	NEW OIL IND	1960	2	1.00	1.00	1.00	0.67	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.25	OIL SELF GEN	1972	2	1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.31	NEW NAT GAS	1960	3	1.00	1.00	1.00	0.82	0	99	¯1	¯1	1.00	0.00	1.00
8.312	NEW GAS	1960	3	1.00	1.00	1.00	0.82	0	150	¯1	¯1	1.00	0.00	1.00
8.314	NEW GAS DIR	1960	3	1.00	1.00	1.00	0.40	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.315	NEW GAS DIR	1960	3	1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.316	NEW GAS DIR	1960	3	1.00	1.00	1.00	0.31	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.317	NEW GAS	1960	3	1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.319	NEW GAS	1960	3	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.32	NEW GAS DIR	1960	3	1.00	1.00	1.00	0.36	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.33	NEW GAS DIRECT	1960	3	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.34	NEW GAS IND	1960	3	1.00	1.00	1.00	0.67	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.41	LIQUOR AND WOOD	1960	9	1.00	1.00	1.00	0.60	¯1	¯1	¯1	¯1	0.40	0.00	1.00
8.519	NEW CAPTIVE GAS	1960	5	1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.58	0.00	1.00
8.612	HEAT PUMP	1960	4	1.00	2.00	1.00	1.00	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.11	OLD COAL	1920	1	1.00	1.00	1.00	0.70	¯1	¯1	¯1	¯1	0.70	0.00	1.00
9.112	OLD COAL	1920	1	1.00	1.00	1.00	0.65	¯1	¯1	¯1	¯1	0.70	0.00	1.00
9.114	OLD COAL DIR	1920	1	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	0.70	0.00	1.00
9.115	OLD COAL DIR	1920	1	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	0.70	0.00	1.00
9.116	OLD DIR COAL	1920	1	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	0.70	0.00	1.00
9.117	OLD COAL	1920	1	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	0.56	0.00	1.00
9.119	OLD COAL	1920	1	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	0.70	0.00	1.00
9.12	OLD COAL DIR	1920	1	1.00	1.00	1.00	0.30	40	600	¯1	¯1	0.21	0.00	1.00
9.13	OLD COAL	1920	1	1.00	1.00	1.00	0.25	¯1	¯1	¯1	¯1	0.70	0.00	1.00
9.14	OLD COAL IND	1920	1	1.00	1.00	1.00	0.62	¯1	¯1	¯1	¯1	0.70	0.00	1.00
9.21	OLD OIL	1920	2	1.00	1.00	1.00	0.71	¯1	¯1	¯1	¯1	0.70	0.00	1.00
9.212	OLD OIL	1920	2	1.00	1.00	1.00	0.72	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.214	OLD OIL DIR	1920	2	1.00	1.00	1.00	0.40	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.215	OLD OIL DIR	1920	2	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.216	OLD OIL DIR	1920	2	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.217	OLD OIL	1920	2	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00

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TECH ID	TECHNOLOGY NAME	SERV SECT	DATA QUALITY MAX FRAC	DATA QUALITY COST	DATA QUALITY ENER SAVE	DATA QUALITY ACCELER	CONST PER (YRS)	PHYS LIFE (YRS)	DOE ACCEL (YRS)	LAST UPDATED	
5.114	NEW COAL DIRECT	14	B	C		C	2.0	25	5	MAR 28, 1978	11:21:06 AM
5.115	NEW COAL DIRECT	15	B	C		C	2.0	10	5	MAR 21, 1978	7:15:28 PM
5.116	NEW COAL DIRECT	16	B	C		C	2.0	25	3	MAR 21, 1978	5:37:24 PM
5.117	NEW COAL DIRECT	17	B	C		C	2.0	25	5	MAR 21, 1978	5:37:30 PM
5.119	NEW COAL DIRECT	19	B	C		C	2.0	25	5	MAR 21, 1978	5:37:36 PM
5.12	NEW COAL DIRECT	2	B	C		C	2.0	25	5	MAR 21, 1978	5:39:25 PM
5.13	NEW COAL DIRECT	3	B	C		C	2.0	25	5	MAR 20, 1978	8:22:22 PM
5.14	NEW COAL IND	4	B	C		C	1.0	25	5	MAR 21, 1978	8:18:21 PM
8.11	NEW COAL BOILER	1	B	A		A	2.5	25	0	MAR 21, 1978	8:17:54 PM
8.112	NEW COAL	12	B	A		A	2.0	25	0	MAR 21, 1978	5:36:48 PM
8.21	NEW OIL	1	B	A		A	1.0	25	0	MAR 21, 1978	7:09:06 PM
8.212	NEW OIL	12	B	A		A	1.0	25	0	MAR 28, 1978	1:22:32 PM
8.214	NEW OIL DIR	14	A	B		A	1.0	25	0	MAR 21, 1978	8:31:23 PM
8.215	NEW OIL DIR	15	A	B		A	1.0	10	0	MAR 21, 1978	7:20:57 PM
8.216	NEW OIL DIR	16	A	B		A	1.0	25	0	MAR 21, 1978	7:21:03 PM
8.217	NEW OIL	17	A	B		A	1.0	25	0	MAR 21, 1978	8:25:53 PM
8.219	NEW OIL	19	A	B		A	1.0	25	0	MAR 21, 1978	7:24:17 PM
8.22	NEW DIR OIL	2	A	B		A	1.5	25	0	MAR 21, 1978	7:25:37 PM
8.23	NEW OIL DIRECT	3	A	B		A	1.5	25	0	MAR 20, 1978	8:23:36 PM
8.24	NEW OIL IND	4	A	B		A	1.0	25	0	MAR 21, 1978	7:26:36 PM
8.25	OIL SELF GEN	5	B	B		B	2.0	25	0	MAR 21, 1978	7:30:16 PM
8.31	NEW NAT GAS	1	A	A		A	1.5	25	0	MAR 28, 1978	11:16:24 AM
8.312	NEW GAS	12	A	A		A	1.0	25	0	MAR 28, 1978	1:21:59 PM
8.314	NEW GAS DIR	14	A	B		A	1.0	25	0	MAR 21, 1978	7:36:02 PM
8.315	NEW GAS DIR	15	A	B		A	1.0	10	0	MAR 21, 1978	7:37:02 PM
8.316	NEW GAS DIR	16	A	B		A	1.0	25	0	MAR 21, 1978	7:37:47 PM
8.317	NEW GAS	17	A	B		A	1.0	25	0	MAR 21, 1978	7:38:52 PM
8.319	NEW GAS	19	A	B		A	1.0	25	0	MAR 21, 1978	7:39:45 PM
8.32	NEW GAS DIR	2	A	B		A	1.0	25	0	MAR 21, 1978	7:40:52 PM
8.33	NEW GAS DIRECT	3	A	B		A	1.0	25	0	MAR 20, 1978	8:24:16 PM
8.34	NEW GAS IND	4	A	B		A	1.0	25	0	MAR 21, 1978	7:41:44 PM
8.41	LIQUOR AND WOOD	1	B	B		A	1.0	25	0	MAR 21, 1978	7:45:05 PM
8.519	NEW CAPTIVE GAS	19	B	B		A	1.0	25	0	MAR 28, 1978	3:08:40 PM
8.612	HEAT PUMP	12	A	B		A	0.3	20	0	MAR 21, 1978	8:33:02 PM
9.11	OLD COAL	1	A	A		A	2.5	25	0	MAR 21, 1978	10:31:56 AM
9.112	OLD COAL	12	A	A		A	1.0	25	0	MAR 21, 1978	10:33:17 AM
9.114	OLD COAL DIR	14	A	A		C	1.0	25	5	MAR 21, 1978	10:40:14 AM
9.115	OLD COAL DIR	15	A	A		C	1.0	5	5	MAR 21, 1978	10:40:07 AM
9.116	OLD DIR COAL	16	A	A		A	1.0	25	0	MAR 21, 1978	10:42:21 AM
9.117	OLD COAL	17	A	A		C	1.0	25	5	MAR 21, 1978	10:42:51 AM
9.119	OLD COAL	19	A	A		C	1.0	25	5	MAR 21, 1978	10:43:29 AM
9.12	OLD COAL DIR	2	A	A		C	2.0	25	5	MAR 21, 1978	10:44:58 AM
9.13	OLD COAL	3	B	B		B	2.0	25	0	MAR 28, 1978	11:30:11 AM
9.14	OLD COAL IND	4	A	A		C	1.0	25	5	MAR 27, 1978	11:34:20 AM
9.21	OLD OIL	1	A	A		A	1.0	25	0	MAR 21, 1978	10:49:04 AM
9.212	OLD OIL	12	A	A		A	1.0	25	0	MAR 21, 1978	10:51:31 AM
9.214	OLD OIL DIR	14	A	A		A	1.0	24	0	MAR 21, 1978	10:52:07 AM
9.215	OLD OIL DIR	15	A	A		A	1.0	5	0	MAR 21, 1978	10:52:41 AM
9.216	OLD OIL DIR	16	A	A		A	1.0	25	0	MAR 21, 1978	10:53:08 AM
9.217	OLD OIL	17	A	A		C	1.0	25	5	MAR 21, 1978	10:53:42 AM

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APPLICABLE INDUSTRIES (MODIFIED SIC CODES)

TECH ID	TECHNOLOGY NAME	20	21	22	23	24	25	26	27	28	29	30	31	32	331	3334	334	34	35	36	37	38	39	01	02	10	14
5.114	NEW COAL DIRECT													1													
5.115	NEW COAL DIRECT													1													
5.116	NEW COAL DIRECT													1													
5.117	NEW COAL DIRECT														1												
5.119	NEW COAL DIRECT														1												
5.12	NEW COAL DIRECT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5.13	NEW COAL DIRECT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5.14	NEW COAL IND									1	1																
8.11	NEW COAL BOILER	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8.112	NEW COAL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8.21	NEW OIL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8.212	NEW OIL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8.214	NEW OIL DIR													1													
8.215	NEW OIL DIR													1													
8.216	NEW OIL DIR													1													
8.217	NEW OIL														1												
8.219	NEW OIL														1												
8.22	NEW DIR OIL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8.23	NEW OIL DIRECT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8.24	NEW OIL IND									1	1																
8.25	OIL SELF GEN	1		1	1	1	1	1	1	1	1	1		1				1	1	1	1	1	1	1	1	1	1
8.31	NEW NAT GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8.312	NEW GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8.314	NEW GAS DIR													1													
8.315	NEW GAS DIR													1													
8.316	NEW GAS DIR													1													
8.317	NEW GAS														1												
8.319	NEW GAS														1												
8.32	NEW GAS DIR	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8.33	NEW GAS DIRECT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8.34	NEW GAS IND									1	1																
8.41	LIQUOR AND WOOD							1																			
8.519	NEW CAPTIVE GAS														1												
8.612	HEAT PUMP	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.11	OLD COAL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.112	OLD COAL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.114	OLD COAL DIR													1													
9.115	OLD COAL DIR													1													
9.116	OLD DIR COAL													1													
9.117	OLD COAL														1												
9.119	OLD COAL														1												
9.12	OLD COAL DIR	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.13	OLD COAL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.14	OLD COAL IND									1	1																
9.21	OLD OIL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.212	OLD OIL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.214	OLD OIL DIR													1													
9.215	OLD OIL DIR													1													
9.216	OLD OIL DIR													1													
9.217	OLD OIL														1												

GENERAL INFORMATION FOR CONVENTIONAL TECHNOLOGIES
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TECH ID	TECHNOLOGY NAME	YEAR AVAIL	FUELS USED	FUEL SHARE (1ST FUEL)	FUEL EFFECIENCY			SIZE RANGE (MMBTU/HR)		LOAD RANGE (HRS/YR)		MAXIMUM FRACTION		
					COMBUSTN	TRANSMIS	FINL USE	LO	HI	LO	HI	INCREMENTL	RETROFIT	CONSERVATN
9.219	OLD OIL	1920	2	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.22	OLD OIL DIR	1920	2	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.23	OLD OIL	1920	2	1.00	1.00	1.00	0.25	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.24	OLD OIL IND	1920	2	1.00	1.00	1.00	0.62	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.31	OLD NAT GAS	1920	3	1.00	1.00	1.00	0.70	¯1	¯1	¯1	¯1	0.20	0.00	1.00
9.312	OLD GAS	1920	3	1.00	1.00	1.00	0.70	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.314	OLD GAS DIR	1920	3	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.315	OLD GAS DIR	1920	3	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.316	OLD DIR GAS	1920	3	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.317	OLD GAS	1927	3	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.319	OLD GAS	1920	3	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.32	OLD GAS DIR	1920	3	1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.33	OLD GAS	1920	3	1.00	1.00	1.00	0.25	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.34	OLD GAS IND	1920	3	1.00	1.00	1.00	0.62	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.41	LIQUOR AND WOOD	1920	9	1.00	1.00	1.00	0.60	¯1	¯1	¯1	¯1	0.27	0.00	1.00
9.519	OLD CAPTIVE GAS	1960	5	1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.58	0.00	1.00
9.612	CONV ELEC HEAT	1920	4	1.00	1.00	1.00	0.90	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.62	CONV ELEC	1920	4	1.00	1.00	1.00	1.00	¯1	¯1	¯1	¯1	1.00	1.00	1.00
9.75	CONV ELECTRICTY	1920	4	1.00	1.00	1.00	0.95	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.76	CONV ELECTRICTY	1920	4	1.00	1.00	1.00	1.00	¯1	¯1	¯1	¯1	1.00	0.00	1.00

GENERAL INFORMATION FOR CONVENTIONAL TECHNOLOGIES continued

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TECH ID	TECHNOLOGY NAME	SERV SECT	DATA QUALITY MAX FRAC	COST	ENER SAVE	ACCELER	CONST PER (YRS)	PHYS LIFE (YRS)	DOE ACCEL (YRS)	LAST UPDATED
9.219	OLD OIL	19	A	A		A	1.0	25	0	MAR 21, 1978 10:54:09 AM
9.22	OLD OIL DIR	2	A	A		A	1.5	25	0	MAR 21, 1978 10:54:35 AM
9.23	OLD OIL	3	B	B		B	1.5	25	0	MAR 28, 1978 11:33:29 AM
9.24	OLD OIL IND	4	A	A		A	1.0	25	0	MAR 27, 1978 11:34:27 AM
9.31	OLD NAT GAS	1	A	A		A	1.0	25	0	MAR 29, 1978 7:36:11 PM
9.312	OLD GAS	12	A	A		A	1.0	25	0	MAR 21, 1978 11:00:37 AM
9.314	OLD GAS DIR	14	A	A		A	1.0	25	0	MAR 21, 1978 11:01:06 AM
9.315	OLD GAS DIR	15	A	A		A	1.0	5	0	MAR 29, 1978 10:47:12 PM
9.316	OLD DIR GAS	16	A	A		A	1.0	25	0	MAR 21, 1978 11:02:07 AM
9.317	OLD GAS	17	A	A		A	1.0	25	0	MAR 21, 1978 11:02:33 AM
9.319	OLD GAS	19	A	A		A	1.0	25	0	MAR 21, 1978 11:03:02 AM
9.32	OLD GAS DIR	2	A	A		A	1.5	25	0	MAR 21, 1978 11:03:26 AM
9.33	OLD GAS	3	B	B		B	1.0	25	0	MAR 28, 1978 11:36:43 AM
9.34	OLD GAS IND	4	A	A		A	1.0	25	0	MAR 27, 1978 11:34:35 AM
9.41	LIQUOR AND WOOD	1	A	A		A	1.0	25	0	MAR 21, 1978 11:05:14 AM
9.519	OLD CAPTIVE GAS	19	B	B		A	1.0	25	0	MAR 28, 1978 3:02:02 PM
9.612	CONV ELEC HEAT	12	A	A		A	0.3	20	0	MAR 21, 1978 11:05:41 AM
9.62	CONV ELEC	2	A	A		A	0.3	20	0	APR 6, 1978 2:55:35 PM
9.75	CONV ELECTRICTY	5	A	A		A	0.0	25	0	MAR 21, 1978 11:06:07 AM
9.76	CONV ELECTRICTY	6	A	A		A	0.0	25	0	MAR 21, 1978 11:06:33 AM

GENERAL INFORMATION FOR CONVENTIONAL TECHNOLOGIES continued

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TECH ID	TECHNOLOGY NAME	20	21	22	23	24	25	26	27	28	29	30	31	32	331	3334	334	34	35	36	37	38	39	01	02	10	14
		APPLICABLE INDUSTRIES (MODIFIED SIC CODES)																									
9.219	OLD OIL														1												
9.22	OLD OIL DIR	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.23	OLD OIL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.24	OLD OIL IND									1	1																
9.31	OLD NAT GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.312	OLD GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.314	OLD GAS DIR													1													
9.315	OLD GAS DIR													1													
9.316	OLD DIR GAS													1													
9.317	OLD GAS														1												
9.319	OLD GAS														1												
9.32	OLD GAS DIR	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.33	OLD GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.34	OLD GAS IND									1	1																
9.41	LIQUOR AND WOOD							1																			
9.519	OLD CAPTIVE GAS														1												
9.612	CONV ELEC HEAT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.62	CONV ELEC	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.75	CONV ELECTRICTY	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
9.76	CONV ELECTRICTY									1					1	1	1										

CONVENTIONAL TECHNOLOGY SPECIFICATIONS

BUILDING BLOCK COEFFECIENT DATA NOT FOUND FOR 9.11 9.112 9.114 9.115 9.116 9.117 9.119 9.12 9.13 9.14 9.21 9.212 9.214 9.215 9.216 9.217 9.219 9.22 9.23 9.24 9.31 9.312 9.314 9.315 9.316 9.317 9.319 9.32 9.33 9.34 9.41 9.519 9.612 9.62 9.75 9.76

BUILDING BLOCK COEFFICIENTS
PRINTED APR 7, 1978 7:09:41 PM

TECH ID 5.114
UPDATED APR 7, 1978 11:11:

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.314	1.00	1.00
C 8.116	1.00	0.87
H 8.11	1.00	1.00
I 8.11	1.00	1.00
G 5.12	1.00	0.72

TECH ID 5.115
UPDATED APR 7, 1978 11:11:33 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.315	1.00	1.14	2.61
C 8.116	1.00	1.03	1.49
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
G 5.12	1.00	0.66	0.90

TECH ID 5.116
UPDATED APR 7, 1978 11:11:

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.316	1.00	1.02
C 8.116	1.00	0.44
H 8.11	1.00	1.00
I 8.11	1.00	1.00
G 5.12	1.00	0.30

TECH ID 5.117
UPDATED APR 7, 1978 11:11:33 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.317	1.00	1.00	0.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
F 8.317	1.00	0.00	1.36
C 8.116	1.00	0.08	2.56
G 5.12	1.00	0.04	0.90

CONVENTIONAL TECHNOLOGY SPECIFICATIONS continued

TECH ID 5.119
UPDATED APR 7, 1978 11:11:33 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.319	1.00	2.14	0.00
F 8.319	1.00	0.00	1.15
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
B 8.116	1.00	0.37	2.95
C 8.116	1.00	0.14	1.49
G 5.12	1.00	0.07	0.66

TECH ID 5.12
UPDATED APR 7, 1978 11:11:33 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.32	1.00	0.00	1.60
B 8.116	1.00	0.00	0.97
C 8.116	1.00	0.00	1.12
H 8.11	1.00	0.00	1.00
I 8.11	1.00	0.00	1.00
G 5.12	1.00	0.00	1.00

TECH ID 5.13
UPDATED APR 7, 1978 11:11:33 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.33	1.00	1.63	8.15
C 8.116	1.00	0.37	1.29
B 8.116	1.00	1.00	5.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
G 5.12	1.00	0.24	1.20

TECH ID 5.14
UPDATED APR 6, 1978 4:27:4

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.34	1.00	6.64
C 8.116	1.00	2.42
D 8.14	1.00	1.00
E 8.14	1.00	1.00
H 8.11	1.00	1.00
I 8.11	1.00	1.00
B 8.116	1.00	4.70
G 5.12	1.00	1.20

CONVENTIONAL TECHNOLOGY SPECIFICATIONS

CONTINUED

TECH ID 8.11
UPDATED APR 4, 1978 3:11:11 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.11	0.83	0.56	2.17
B 8.11	0.83	0.62	1.86
C 8.11	0.83	0.58	2.05
D 8.11	0.83	0.61	1.91
E 8.11	0.83	0.63	1.85
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 8.112
UPDATED APR 7, 1978 11:49:16 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.11	0.83	0.31	1.00
B 8.11	0.83	0.39	1.00
C 8.11	0.83	0.33	1.00
D 8.11	0.83	0.37	1.00
E 8.11	0.83	0.39	1.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 8.21
UPDATED APR 4, 1978 3:32:26 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.11	0.48	0.57	2.08
B 8.11	0.29	0.53	2.30
C 8.11	0.50	0.64	1.80
D 8.11	0.04	0.59	1.98
E 8.11	0.70	0.59	2.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 8.212
UPDATED APR 7, 1978 11:50:40 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.11	0.48	0.33	1.00
B 8.11	0.29	0.29	1.00
C 8.11	0.50	0.41	1.00
D 8.11	0.04	0.36	1.00
E 8.11	0.70	0.41	1.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

CONVENTIONAL TECHNOLOGY SPECIFICATIONS

CONTINUED

TECH ID 8.214
UPDATED APR 6, 1978 3:20:0

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.314	1.00	1.00
C 8.216	1.00	1.97
H 8.11	1.00	1.00
I 8.11	1.00	1.00

TECH ID 8.215
UPDATED APR 6, 1978 3:27:55 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.315	1.00	1.00	2.29
C 8.216	1.00	2.37	3.54
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 8.216
UPDATED APR 6, 1978 3:27:5

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.316	1.00	1.00
B 8.116	1.00	0.00
C 8.216	1.00	1.00
D 8.116	1.00	0.00
H 8.11	1.00	1.00
I 8.11	1.00	1.00

TECH ID 8.217
UPDATED APR 6, 1978 3:27:55 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.317	1.00	1.00	0.00
C 8.216	1.00	0.18	6.65
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
F 8.317	1.00	0.00	1.00

TECH ID 8.219
UPDATED APR 6, 1978 3:27:55 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.319	1.00	1.00	0.00
F 8.319	1.00	0.00	1.00
C 8.216	1.00	0.35	3.53
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

CONVENTIONAL TECHNOLOGY SPECIFICATIONS

CONTINUED

TECH ID 8.22
UPDATED APR 6, 1978 3:34:20 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.32	1.00	0.00	1.00
C 8.216	1.00	0.00	0.97
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
A 8.99	1.00	1.50	0.00
B 8.99	1.00	1.65	0.00
E 8.99	1.00	1.70	0.00

TECH ID 8.23
UPDATED APR 6, 1978 4:53:26 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.33	1.00	1.31	6.55
C 8.216	1.00	1.00	5.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 8.24
UPDATED APR 6, 1978 3:34:2

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.34	1.00	1.16
C 8.24	1.00	1.00
I 8.11	1.00	1.00
H 8.11	1.00	1.00
B 1.14	1.00	0.10

TECH ID 8.25
UPDATED APR 4, 1978 2:16:16 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.11	0.48	0.64	2.08
B 8.11	0.30	0.64	2.30
C 8.11	0.50	0.64	1.80
D 8.11	0.04	0.64	1.98
E 8.11	0.70	0.64	2.00
H 8.11	0.90	1.00	1.00
I 8.11	1.00	1.00	1.00
C 5.71	2.50	0.23	1.00
B 8.15	1.00	0.35	1.00

CONVENTIONAL TECHNOLOGY SPECIFICATIONS

CONTINUED

TECH ID 8.31
UPDATED APR 4, 1978 3:11:11 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.11	0.46	0.57	2.10
B 8.11	0.29	0.53	2.30
C 8.11	0.50	0.64	1.80
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
E 8.11	0.70	0.59	2.00

TECH ID 8.312
UPDATED APR 7, 1978 11:51:50 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.11	0.46	0.32	1.00
B 8.11	0.29	0.28	1.00
E 8.11	0.70	0.41	1.00
C 8.11	0.50	0.41	1.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 8.314
UPDATED APR 6, 1978 3:54:5

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.314	1.00	1.00
C 8.216	1.00	1.97
H 8.11	1.00	1.00
I 8.11	1.00	1.00

TECH ID 8.315
UPDATED APR 6, 1978 3:56:11 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.315	1.00	1.00	1.00
C 8.216	1.00	2.37	3.54
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 8.316
UPDATED APR 6, 1978 3:57:3

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.316	1.00	1.00
C 8.216	1.00	1.00
H 8.11	1.00	1.00
I 8.11	1.00	1.00

CONVENTIONAL TECHNOLOGY SPECIFICATIONS

CONTINUED

TECH ID 8.317
UPDATED APR 6, 1978 3:58:50 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.317	1.00	1.00	0.00
C 8.216	1.00	0.18	6.65
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
F 8.317	1.00	0.00	1.00

TECH ID 8.319
UPDATED APR 6, 1978 4:00:38 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.319	1.00	1.00	0.00
F 8.319	1.00	0.00	1.00
C 8.216	1.00	0.35	3.53
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 8.32
UPDATED APR 6, 1978 3:50:13 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.32	1.00	0.00	1.00
C 8.216	1.00	0.00	0.97
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
A 8.99	1.00	1.00	0.00
B 8.99	1.00	1.00	0.00

TECH ID 8.33
UPDATED APR 6, 1978 3:51:58 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.33	1.00	1.00	4.97
C 8.216	1.00	1.00	5.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 8.34
UPDATED APR 6, 1978 3:53:0

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.34	1.00	1.00
C 8.24	1.00	1.00
H 8.11	1.00	1.00
I 8.11	1.00	1.00

CONVENTIONAL TECHNOLOGY SPECIFICATIONS
CONTINUED

TECH ID 8.41
UPDATED MAR 23, 1978 5:09:59 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.11	0.83	0.56	2.17
B 8.11	0.83	0.52	1.75
C 8.11	0.83	0.30	1.10
D 8.11	0.83	0.17	0.61
E 8.11	0.83	0.52	1.70
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 8.519
UPDATED APR 7, 1978 11:11:33 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.319	1.00	1.00	0.00
F 8.319	1.00	0.00	1.00
C 8.216	1.00	0.35	3.53
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 8.612
UPDATED MAR 17, 1978 9:55:24 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.612	1.00	0.30	1.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

CONVENTIONAL BUILDING BLOCKS

BUILDING BLOCKS
PRINTED APR 7, 1978 7:17:02 PM

ID: A 8.11
NAME: SITE PREP
LAST UPDATED MAR 12, 1978 6:30:33 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.03
FREQUENCY AND COST DATA:

0.500	541.000
0.400	823.000
0.100	1,761.000
0.000	0.000

ID: A 8.314
NAME: PRIMARY SYSTEM
LAST UPDATED MAR 21, 1978 10:15:38 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 40
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	500.000
0.550	527.000
0.150	703.000
0.000	0.000

ID: A 8.315
NAME: PRIM SYS GAS GLASS MLTG BATH
LAST UPDATED MAR 21, 1978 10:11:12 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 41.6
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	630.000
0.600	663.000
0.100	884.000
0.000	0.000

ID: A 8.316
NAME: PRIMARY SYSTEM CONVENTIONAL GAS
LAST UPDATED MAR 21, 1978 10:05:57 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 13.1
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	211.000
0.600	223.000
0.100	297.000
0.000	0.000

CONVENTIONAL BUILDING BLOCKS continued

ID: A 8.317
NAME: PRIMARY SYSTEM BLAST FURN STIOVE
LAST UPDATED MAR 21, 1978 10:03:43 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 1.6
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.400	24.000
0.500	25.000
0.100	33.000
0.000	0.000

ID: A 8.319
NAME: PRIMARY SYSTEM (SMALL SIZE CLASS)
LAST UPDATED MAR 21, 1978 10:02:01 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 3
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.400	50.000
0.400	71.000
0.200	114.000
0.000	0.000

ID: A 8.32
NAME: DIRECT GAS PRIMARY SYSTEM
LAST UPDATED MAR 21, 1978 10:19:11 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	695.000
0.500	772.000
0.200	849.000
0.000	0.000

ID: A 8.33
NAME: NEW DIRECT GAS
LAST UPDATED MAR 21, 1978 10:20:56 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 10
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	167.000
0.[illegible]00	238.000
0.200	381.000
0.000	0.000

ID: A 8.34
NAME: PRIM SYS ATM DIST AND CAT REF
LAST UPDATED MAR 21, 1978 10:29:49 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	1,865.000
0.600	1,963.000
0.100	2,617.000
0.000	0.000

ID: A 8.612
NAME: ELEC SP HT
LAST UPDATED MAR 25, 1978 5:41:10 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.02
FREQUENCY AND COST DATA:

0.500	1,500.000
0.400	1,650.000
0.100	2,000.000
0.000	0.000

ID: A 8.99
NAME: SITE PREP
LAST UPDATED MAR 17, 1978 10:22:27 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 10
TYPE S
FRACTION OF COSTS FOR O+M: 0.01
FREQUENCY AND COST DATA:

0.300	5.000
0.600	20.000
0.100	60.000
0.000	0.000

ID: B 1.14
NAME: PARTICULATE CONTROL
LAST UPDATED MAR 17, 1978 9:01:05 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

1.000	1,220.000
0.000	0.000
0.000	0.000
0.000	0.000

CONVENTIONAL BUILDING BLOCKS continued

ID: B 8.11
NAME: BOILER EQUIPMENT (GENERAL)
LAST UPDATED MAR 12, 1978 6:54:53 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.115
FREQUENCY AND COST DATA:

0.350	1,500.000
0.550	2,100.000
0.100	2,520.000
0.000	0.000

ID: B 8.116
NAME: PARTICULATE CONTROLS
LAST UPDATED MAR 14, 1978 3:09:18 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 13.1
TYPE S
FRACTION OF COSTS FOR O+M: 0.03
FREQUENCY AND COST DATA:

1.000	184.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: B 8.15
NAME: EQUIPMENT TURBINE
LAST UPDATED MAR 22, 1978 1:25:55 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

1.000	5,533.500
0.000	0.000
0.000	0.000
0.000	0.000

ID: B 8.99
NAME: EQUIP COST
LAST UPDATED MAR 17, 1978 10:23:08 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 10
TYPE S
FRACTION OF COSTS FOR O+M: 0.08
FREQUENCY AND COST DATA:

0.200	36.000
0.500	47.000
0.300	58.000
0.000	0.000

CONVENTIONAL BUILDING BLOCKS continued

ID: C 5.71
NAME: DEMAND CHARGE
LAST UPDATED APR 7, 1978 3:53:57 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE L
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.030	1.500
0.940	3.580
0.030	5.670
0.000	0.000

ID: C 8.11
NAME: FUEL HANDLING
LAST UPDATED MAR 13, 1978 3:43:03 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.12
FREQUENCY AND COST DATA:

1.000	467.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: C 8.116
NAME: FL HDLG INC PLVRD AND INV
LAST UPDATED APR 6, 1978 2:40:21 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 13.1
TYPE S
FRACTION OF COSTS FOR O+M: 0.12
FREQUENCY AND COST DATA:

0.400	480.000
0.300	660.000
0.300	1,010.000
0.000	0.000

ID: C 8.216
NAME: FUEL HANDLING (OIL)
LAST UPDATED MAR 18, 1978 6:15:06 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 13.1
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

0.500	77.000
0.500	92.000
0.000	0.000
0.000	0.000

CONVENTIONAL BUILDING BLOCKS continued

ID: C 8.24
NAME: FUEL HANDLING OIL
LAST UPDATED MAR 14, 1978 3:42:42 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE 5
FRACTION OF COSTS FOR O+M: 0.06
FREQUENCY AND COST DATA:

0.500	469.000
0.500	563.000
0.000	0.000
0.000	0.000

ID: D 8.11
NAME: ENVIRONMENTAL CONTROL SYSTEM
LAST UPDATED MAR 12, 1978 6:57:38 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE 5
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

1.000	2,340.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: D 8.116
NAME: SO_2 CONTROL AND WASTE HANDLING
LAST UPDATED MAR 14, 1978 3:12:39 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 13.1
TYPE 5
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

1.000	1,090.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: D 8.14
NAME: SULFUR CONTROL AND FUEL HDLG
LAST UPDATED MAR 14, 1978 3:46:55 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE 5
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

1.000	3,709.000
0.000	0.000
0.000	0.000
0.000	0.000

CONVENTIONAL BUILDING BLOCKS continued

ID: E 8.11
NAME: FEEDWATER SYSTEM AND UTILITIES
LAST UPDATED MAR 12, 1978 7:01:07 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.07
FREQUENCY AND COST DATA:

0.200	210.000
0.500	260.000
0.300	660.000
0.000	0.000

ID: E 8.14
NAME: UTILITIES
LAST UPDATED MAR 17, 1978 4:05:11 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE S
FRACTION OF COSTS FOR O+M: 0.06
FREQUENCY AND COST DATA:

0.500	2,321.000
0.400	2,785.000
0.100	3,100.000
0.000	0.000

ID: E 8.99
NAME: UTILITIES
LAST UPDATED MAR 17, 1978 10:23:41 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 10
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

1.000	2.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: F 8.317
NAME: PRIM SYS BLST FURN HYRCAR INJ
LAST UPDATED MAR 22, 1978 7:50:20 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 133
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.400	2,015.000
0.500	2,121.000
0.100	2,828.000
0.000	0.000

CONVENTIONAL BUILDING BLOCKS continued

```
ID:   F 8.319
NAME:  PRIM SYS LARGE SIZE
LAST UPDATED MAR 22, 1978  7:49:25 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR):  60
TYPE S
FRACTION OF COSTS FOR O+M:  0.1
FREQUENCY AND COST DATA:
  0.400        1,000.000
  0.400        1,250.000
  0.200        1,750.000
  0.000            0.000

ID:   G 5.12
NAME:  PULVERIZER FOR DIRECT COAL
LAST UPDATED APR 6, 1978  2:52:10 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR):  50
TYPE S
FRACTION OF COSTS FOR O+M:  0.05
FREQUENCY AND COST DATA:
  1.000          486.000
  0.000            0.000
  0.000            0.000
  0.000            0.000

ID:   H 8.11
NAME:  INDIRECT CAPITAL COSTS (ENGIN, CONTIN)
LAST UPDATED MAR 12, 1978  7:08:23 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR):  0
TYPE M
FRACTION OF COSTS FOR O+M:  0
FREQUENCY AND COST DATA:
  0.550            1.300
  0.350            1.400
  0.100            1.500
  0.000            1.650

ID:   I 8.11
NAME:  CONSTRUCTION INDICES
LAST UPDATED MAR 12, 1978  7:09:36 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR):  0
TYPE M
FRACTION OF COSTS FOR O+M:  0
FREQUENCY AND COST DATA:
  0.400            0.870
  0.400            0.970
  0.200            1.070
  0.000            1.250

PROGRAM EXITED
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CHAPTER III

FOSSIL ENERGY TECHNOLOGIES

A. Introduction

Three main classes of technologies are included in this section, atmospheric fluidized bed combustion technologies, low Btu gasification and medium Btu gasification technologies. To achieve an understanding of the estimation procedures used to derive the cost distribution for these technologies Volume I, chapter II, the first two sections of this appendix along with the discussion of technology 8.11 conventional coal steam should all be read.

The format for this section is to discuss each fossil energy technology and its application in all service sectors at one time. This differs from the previous section where the technologies were discussed by service sector. Since all three of the fossil energy technologies in ISTUM are coal based technologies, some cost estimates are made by looking at the expected cost differential between the fossil energy technology and the better known costs for conventional coal. A familiarity with the procedures used to estimate the costs for conventional coal steam ID8.11 is necessary to the understanding of the fossil energy technology documentation.

B. Technology 1.1 - Atmospheric Fluidized Bed Combustion (AFB)

Atmospheric fluidized bed combustion competes in three service sectors, steam, space heat and coal capable indirect heat. In the steam and space heat service sectors the cost components that define AFB are very similar to the conventional coal cost components. As was the case with conventional coal steam, costs for a 120 MMBtu/hr unit and a 250 MMBtu/hr unit were estimated directly. To obtain a cost estimate of a 50 MMBtu/hr unit an exponential scaler was calculated from the cost information available on the 120 MMBtu/hr and 250 MMBtu/hr. This was used to scale the 120 MMBtu/hr costs down to 50 MMBtu/hr. This is the same procedure used in conventional coal steam ID 8.11.

Since the AFB boiler is a coal based technology it was assigned a maximum fraction of .70. This reflects the fact that the nonattainment regulations will preclude the use of coal in certain areas and that some industrial plants in urban areas will not have land available to allow for coal handling equipment.

1. Technology 1.11 - Atmospheric Fluidized Bed Combustion in The Steam Service Sector.

DISCUSSION OF BUILDING BLOCKS

a) Building Block A8.11 - Site Preparation and Power House

This component is similar to the site preparation and power house component for coal boilers. An AFB boiler is slightly smaller than a coal boiler and since no scrubber is required the overall land area required is less. This results in lower site preparation and power house costs. The calculated costs are:

AFB Site Preparation and Power House Costs (100 MMBtu/hr)

low cost	404
medium cost	437
high cost	525

The three cost cases are defined the same as in the conventional coal steam technology.

Incorporating the site related factors that occur in other building blocks in the same manner as was done for building block A8.11 in conventional coal results in final site preparation and power house costs of:

AFB SITE PREPARATION AND POWER HOUSE COSTS
Unit size is 100 MMBtu/hr steam
(costs in thousands of 1977 $'s)

	frequency	capital cost	O&M
low cost	.5	404	12
medium cost	.4	650	20
high cost	.1	1450	43

b) Building Block B1.11 - AFB Boiler Equipment

This building block represents the costs of the actual AFB boiler including a carbon burn up cell and the coal-limestone feeding system. At this time there is no proven coal feed system for AFB boilers larger than 100 MMBtu/hr Favorable assumptions concerning the cost and design of the coal feed system are incorporated in these estimates.

The primary source for the AFB equipment estimates was an Atmospheric Fluidized Bed Cost Study[1/] prepared by EEA. For this study three European companies who currently design and/or build fluidized bed combustion units were contacted and asked to prepare capital cost and operation and maintenance cost estimates for various sized AFB units. These cost estimates were supplemented by EEA's engineering experience and other available studies.

The ISTUM AFB boiler equipment estimates for a 100 MMBtu/hr unit are:

low cost case	$2,800,000
medium cost case	$3,100,000
high cost case	$3,640,000

The low cost case represents a single bed AFB unit. The medium cost case requires a multiple bed unit designed to meet increased turndown requirements. The high cost case reflects the installation of two 50 percent capacity AFB units to provide increased reliability[2/]. If one AFB unit is shut down the plant can still operate at fifty percent capacity.

c. Building Block C8.11 - Fuel Handling

Since the efficiency of AFB is assumed to be .82, the same as conventional coal steam, the coal handling costs that were applicable to technology 8.11, conventional coal steam are also applicable here. In addition to coal, an AFB boiler requires substantial amounts of limestone, usually three to four times the amount required by a flue gas scrubber. The handling

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1/ "Atmospheric Fluidized Bed/Cost Study", prepared for the Office of Policy and Evaluation, DOE; by Energy and Environmental Analysis, Inc., June 5, 1978.

2/ This is discussed more completely technology 8.11 conventional coal steam, building block B8.11.

costs of the limestone are added onto the coal handling costs. This increases the fuel handling costs by approximately 30 percent. This substantial cost increase results from having to store the limestone in a bin or silo to keep it dry.

The amount of limestone that is required to be stored depends upon the sulfur content of the coal and the SO_2 absorption characteristics of the limestone. For a coal with four percent sulfur content a limestone to coal ratio of approximately 1:3 by weight will be required to meet a 80 percent SO_2 removal standard. If dolomite is used in the place of limestone, the required coal-sorbent ratio may double.

Since limestone is much denser than coal, it weighs approximately 90 lbs/ft^3 compared to 50 lbs/ft^3 for coal, a proportionately smaller silo or bin is required. A precast concrete silo capable of holding 1200 tons of limestone is estimated by Richardson[1/] at $60,000. The additional cost of foundation and weather protection is assumed to be $20,000. The cost of accumulating a thirty day stockpile assuming 40 tons of limestone is required per day for a 120 MMBtu/hr unit at a cost of $17.50 per ton of limestone is $21,000. The cost of unloading facilities, and screw or pneumatic reclaim equipment is estimated to add $40,000 to the total costs.

Limestone Handling Costs

Silo	$80,000
Stockpile	$21,000
Unloading and reclaim equipment	$40,000
TOTAL	$141,000

The low cost case for limestone is then $141,000. The medium cost case is 10 percent higher and results from undesirable

1/ Richardson, op. cit.

site factors. The high cost case is roughly double the best case and results from either severe site constraints such as a shortage of land or the use of a limestone with poor SO_2 absorbancy which results in a higher limestone-coal ratio.

COAL AND LIMESTONE HANDLING COSTS
(120 MMBtu/hr Unit)

	frequency	Limestone Capital Costs	Coal Capital Costs	TOTAL Costs
low cost	.4	141,000	467,000	608,000
medium cost	.3	155,000	547,000	702,000
high cost	.3	280,000	897,000	1,177,00

Operating and maintenance costs were calculated to be 12 percent of capital costs. The size scalers were determined in the same manner as the conventional coal scalers. See technology 8.11 writeup.

d) Building Block D8.11 - Environmental and Waste Removal Costs

The AFB unit removes the SO_2 during the combustion of the coal so there is no scrubber required. This building block reflects only the costs of a fabric filter and solid waste removal. The amount of solid waste produced by an AFB unit, ash and spent sorbent, is approximately the same as the amount produced by the same size coal boiler with scrubber. The costs in this building block are the same as those for the conventional coal, only the costs of the scrubber have been subtracted out.

e) Building Block E8.11 - Feedwater Treatment and Auxiliaries

This building block includes the cost of feedwater treatment, electrical switches and general electrical equipment.

The feed water treatment, is identical to that required for conventional coal steam, but the electrical equipment will be a more expensive due to the electricity demands of the bed start-up equipment. In general the costs were found to be 8 percent more expensive than for conventional coal steam.

f) Building Blocks H8.11 and I8.11 - Indirect Capital Costs and Regional Indices

These building blocks are identical to those specified for conventional coal technology 8.11.

2. Technology 1.112-Atmospheric Fluidized Bed Combustion in the Space Heat Service Sector

The costs calculated for AFB in the steam service sector are used to estimate the costs for AFB in the space heat service sector. 1/ To adjust for the different sized units, 25 MMBtu/hr and 100 MMBtu/hr, the exponential scalers calculated from AFB in the steam service sector are used to determine the costs of the 25 MMBtu/hr size relevant here.

1/ See the discussion in Chapter II concerning conventional space heat technology costs where the cost sensitivity to different pressure and temperature requirements is discussed.

3. Technology 1.14-Atmospheric Fluidized Bed Combustion in the Indirect Heat Service Sector

The costs for the use of coal in an atmospheric fluidized bed tubestill heater or furnace were estimated by determining the differential costs between a fluidized bed unit and a conventional coal fired indirect heat unit (technology 5.14). In the low cost case an AFB unit would be 10 percent to 15 percent cheaper than a conventional coal capable tubestill heater. This is due to the higher heat transfer rates and the resulting smaller furnace volume. In addition the fluidized bed should produce a more even heat than a conventional coal unit. However the medium and high cost cases for AFB indirect heat is estimated to be higher than those for conventional coal use. An atmospheric fluidized bed unit can operate efficiently only at temperatures between 1500 $^{\circ}F$ and 1700 $^{\circ}F$. At temperatures outside of this range the SO_2 removal requires a much higher sorbent to coal ratios. This can greatly increase operating costs. In addition, the higher heat transfer rates may require a higher velocity for the fluid passing through the heater. This also tends to increase capital costs.

C. Technology 1.2 - Low Btu Gasification of Coal (LBG)

The general approach used to incorporate LBG into the ISTUM model was to set up a separate set of building blocks that specified the costs of producing the gas. This set of building blocks was scaled up or down depending upon the size requirements of the particular service sector. These LBG base production costs were then combined with the costs of the natural gas combustor for each service sector. This assumes that the costs of a combustor capable of burning natural gas is a good estimate of the costs of a combustor capable of burning low Btu gas.[1/]

A discussion of the choice of gas clean up systems for each service sector application is presented in Volume I, pp. II-28 to II-31. In general the gas cleanup system chosen represents the most favorable system economically for that service sector. In some cases where SO_2 removal was required it was found to be cost effective to burn the hot raw gas and clean the resulting flue gas. Like the other coal based technologies, the maximum fraction for LBG was assumed to be .70 due to the non-attainment regulations and sites where no land is available for coal handling. There is one exception to this .70 maximum fraction assumption and that is in the steam sector where it is assumed that the hot raw gas is combusted in the boiler directly and the SO_2 is removed by scrubbing the flue gas. Industries that place a premium on reliability may be unwilling to burn the hot raw gas directly.[2/] To compensate, the maximum fraction in the steam sector is specified as .50.

1/ Even though the costs of a natural gas boiler can not be retrofit to combust LBG, the costs of a new combustor designed to burn LBG should be very similar to the costs of a new natural gas combustor.

2/ See the discussion in Volume I, p. II-30.

1. LBG Production Costs

Costs were derived for two LBG system sizes, 100 MMBtu/hr and 250 MMBtu/hr of gas produced. The building block structure of LBG relates closely to that of technology 8.11 conventional coal. Many of the costs generated for technology 8.11 served as bench marks for the estimated LBG costs.

a. Building Block Al.22 - Site Preparation and Power House Costs

For a 100 MMBtu/hr system the amount of land required is estimated to be slightly under one acre. The costs of grading, clearing and dirt fill were calculated by the same methods used for building block A8.11 in conventional coal. The power house required for the LBG system[1/] is approximately the same size as that required for a coal boiler. The resulting site preparation and power house costs for the LBG system are very close to the costs calculated for the coal boiler. Since this building block is for a 100 MMBtu/hr unit where the coal boiler building block was sized at 120 MMBtu/hr, the LBG costs are slightly less. Another difference between the two building blocks is that site factors from other blocks were not incorporated into the LBG site preparation costs.[2/]

The final cost estimates for the two LBG sizes are:

Al.22 Site Preparation and Power House

	freq.	100 MMBtu/hr capital cost	250 MMBtu/hr capital cost
low cost	.4	463,000	787,000
medium cost	.4	476,000	809,000
high cost	.2	540,000	910,000

1/ Includes the gas cleanup system.

2/ See the discussion of building block A8.11 for conventional coal steam ID 8.11.

The low medium and high cost cases are defined in the same as they were for conventional steam. The costs for the 100 MMBtu/hr unit went into building block A1.22 and the costs for the 250 MMBtu/hr unit were used to calculate the exponential scaler used to adjust the building block costs to other sizes.

The exponential scaler is determined by first calculating the size coefficient required to scale the 100 MMBtu/hr costs up to the 250 MMBtu/hr size. This size coefficient is found by:

$$.4\left(\frac{787}{463}\right) + .4\left(\frac{809}{476}\right) + .2\left(\frac{918}{540}\right) = 1.69$$

The exponential scaler is found by:

$$\left(\frac{100}{250}\right)^{x} = \frac{1.0}{1.69}$$

exponential scaler x = .573

This scaler is used to scale the site preparation and and power house costs up or down to the sizes required by each service sector.

b. Building Block B1.22 - LBG Equipment

The costs of the actual gasifier were obtained from three sources.[1,2,3] The gasifier is assumed to be of the "fixed bed"

1/ Market Potential for Low and Medium Btu Gas, prepared for the Executive Office of the President, Energy Policy and Planning by Energy and Environmental Analysis Inc., Oct. 27, 1977.

2/ Fixed Bed Coal Gasification for Production of Industrial Fired Gas, DOE report FE-2220-26 by Energy Research Division, Gilbert Associates, Oct. 1977.

3/ Production and Use of Low and Medium Btu Gas, by Energy Research Division, Gilbert Associates, presented at the 5th Energy Technology Conference - March 1, 1978.

type where a cylindrical steel shell, either water jacketed or refractory lined, contains a coal bed up through which air and steam is passed inducing the chemical reaction. This technology has been available for over a decade and is the one most seriously considered for industrial applications due to small sizes available, high reliability and simplicity of operation.

The Gilbert Associates paper quoted gasifier costs from five different suppliers. A very wide range of costs, from $350,000 to $1,500,000 for a 100 MMBtu/hr unit, was found. These costs include the gasifier, cyclones and gas manifold. The cost variability results from different design characteristics and the amount of process by-products produced. Some quotes represented a state of the art, higher quality gasifier. Our cost estimates are designed to allow the most favorable gasifier, economically, to compete for at least a portion of the market. The capital cost distribution used in ISTUM is:

LBG Equipment Costs

(thousands of 1977 $'s)

	freq.	100 MMBtu/hr capital cost	250 MMBtu/hr capital cost
low cost	.3	350	788
medium cost	.5	930	2,093
high cost	.2	1,312	2,952

The high end of the distribution represents the higher quality, more reliable gasifiers. No attempt was made to try to account for saleable or useable by-products of the gasification process.

The exponential scaler for this building block is found by the same procedure used in building block A1.22. The calculations are:

$$250 \text{ MMBtu/hr size coeff.} = .3\,\frac{788}{350} + .5\,\frac{2098}{930} + .2\,\frac{2952}{1.312} + 2.25$$

The exponential scaler is then:

$$\left(\frac{250}{100}\right)^{x} = \frac{2.25}{1.00} \qquad x = .88$$

Operating and maintenance costs are estimated to be ten percent of capital costs.

c. Building Block C1.22 - Coal Handling Equipment

The costs in this building block are taken from the costs calculated for technology 8.11, conventional coal steam. Adjustments are made for the different efficiencies and sizes. They reflect the costs of coal handling equipment required for the production of 100 MMBtu/hr of dirty gas with a gasifier efficiency of .90. The calculated coal handling costs are:

C1.22 LBG Coal Handling Costs
(thousands of 1977 $'s)

	freq.	100 MMBtu/hr capital cost	250 MMBtu/hr capital cost
low cost	.3	332	690
medium cost	.4	515	1,035
high cost	.3	706	1,445

Calculation of the exponential scaler results in a scaler of .78. Operation and maintenance costs are estimated as 12 percent of equipment costs.

d. Building Block D1.22 - Gas Cleanup and Environmental Costs

The costs in this building block result from the removal of all tars, oils and sulfur from the raw gas. A water wash and electrostatic precipitator is used to condense and remove the tars and oils. The gas is chemically washed to remove the hydrogen cyanide and then a Stretford system is used to remove the sulfur. This cleaning process has an efficiency of 82 percent.

The costs for gas cleanup were obtained from Gilbert Associates[1/]. The vendor quotations for gas cleanup equipment were all very close. Tar and oil removal costs are estimated at $747,000. The chemical wash and Stretford unit at $1,375,000. The major source of cost variability is the result of site related factors.

D1.22 Gas Cleanup Costs
(thousands of 1977 $'s)

	100 MMBtu/hr capital cost	250 MMBtu/hr capital cost
low cost	2122	3820
medium cost	2375	4275
high cost	2710	4878

The exponential scaler for this building block is calculated in the same manner as the previous building blocks and is .64.

e. Building Block E1.22 - LBG Auxiliary Equipment

A low Btu gasifier has substantial electricity requirements both for the coal handling equipment and the gasifier itself. Water piping and a steam system for start up is also required.

The cost for all auxiliaries is estimated at $141,000[1/]. Cost variability is the result of site differences and differing equipment design.

E1.22 LBG Auxiliary Equipment
(thousands of 1977 $'s)

	100 MMBtu/hr capital cost	250 MMBtu/hr capital cost
low cost	141	445
medium cost	154	486
high cost	179	563

The calculated exponential scaler for this building block is .64 . The operating and maintenance costs are estimated at 10 percent of equipment costs.

f. LBG Indirect Capital Costs and Regional Indices

The indirect capital cost building block H8.11 and the regional indices building block I8.11 are the same as those used in technology 8.11, conventional coal steam.

2. LBG Combustion and Service Sector Applications

To incorporate the LBG technology into each service sector the following procedure was used. First, the gasifier was sized to meet the Btu input requirement of the natural gas technology in each service sector. For example, technology 8.316 is natural gas in the brick firing service sector. It has one size, 13.1 MMBtu/hr, and an efficiency of .31. The required Btu fuel input is 42 MMBtu/hr. The LBG production building blocks A1.22 through E1.22 are then scaled to this 42 MMBtu/hr size using the exponential scalers calculated for each building block. The size coefficient on B1.22 would be:

$$\left(\frac{42}{100}\right)^{.88} = .47$$

where .88 is the exponential scaler calculated for building block B1.22. Once the LBG production building blocks are scaled appropriately, the natural gas building blocks are added to the technology specification to incorporate the costs of combusting the gas. This procedure was repeated for every service sector.

For some service sectors different assumptions were made concerning the required gas clean up. To adjust these costs the gas cleanup building block was left out of applications where the hot, raw gas could be consumed directly, and was adjusted in those applications that required only tar and oil removal.

D. Technology 1.3 - Medium Btu Gasification (MBG)

The medium Btu gasification technologies in the ISTUM model all assume an industrial park scenario where a large MBG plant serves a number of industrial users. On site production of MBG was considered, but an examination of potential industrial users showed that few, if any, would build new grass roots plants or plant expansions at a size able to support on site production of MBG.[1/] However, on site production may occur through retrofit applications. The combustion properties of MBG allow for it to be burned in conventional natural gas boilers with only slight equipment modification. If the economics favor a switch from natural gas and oil to coal fired systems, then it may be cheaper for a plant to retrofit their existing equipment to combust medium Btu gas than to replace it with direct coal capable or low Btu gas capable combustors. The present version of ISTUM does not deal with retrofit applications. This results in considerably understating the potential market for medium Btu gas production.

The incorporation of medium Btu gasification into each service sector, follows the same procedure used for low Btu gasification . A set of building blocks that specify the costs of producing the gas are calculated. To incorporate the costs of the MBG combustor, the blocks used to specify the costs of the natural gas technology for each service sector are combined with the set of blocks specifying the production costs. This gives a distribution incorporating the costs of producing and combusting the medium Btu gas.

1/ This is discussed in Volume 1, Chapter II p. II-31 to II-35.

Since retrofit applications are excluded, the most economic application of medium Btu gas production is in an industrial park comprised of a number of industrial users. To determine the dimensions of variability costs were calculated for three different sizes of MBG plants each with a different distribution system. The three sizes of MBG plants were 50 MMMBtu/day, 100 MMMBtu/day and 250 MMMBtu/day. A paper by Gilbert Associates[1/] provided much of the cost information used in this analysis. Gilbert provides a cost breakdown for MBG plants sized at 100 MMMBtu/day and 150 MMMBtu/day. To obtain costs for the 50 MMMBtu/day and 250 MMMBtu/day plant a linear extrapolation through the 100 and 250 MMMBtu/day sized plants was used for each building block. The 50 MMBtu/day plant proved not to be economically competitive and was dropped in the final base case run.

Once costs were obtained for the MBG plant and distribution system, costs were allocated to individual industrial users based on the proportion of total gas output they consumed. For example, if the MBG plant produces 100 MMMBtu/day and an industrial user consumes 10 MMMBtu/day then that user incurs one tenth of all costs associated with the MBG production and distribution regardless of location. Of course many other pricing schemes can be devised each with its own advantages and disadvantages. The use of a marginal pricing system was considered but it proved too complicated for this analysis, particularly with the number of industrial park scenarios conceivable. The pricing scheme used in ISTUM allows you to determine the costs allocated to a particular sized plant without having to consider its location in relation to the spatial arrangement of all

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1/ "Production and Use of Low and Medium Btu Gas", Presented at 5th Energy Technology Conference, February 27, 1978 by by the Energy Research Division of Gilbert Associates.

other plants in the MBG park. The only variable that must be known in addition to the costs of the MBG plant is the cost of the total distribution system.

MBG PRODUCTION COSTS

a) Building Block A1.31 Site Preparation, Power House and Utilities

The costs for the best case were obtained from the Gilbert Associates paper. The variability within this building block was determined by examining the variability existing in the other ISTUM coal technologies. The degree of variability in all the MBG production components is less than what occurs in the other coal technologies due to economies of scale associated with the size of the plant and the flexibility accorded to new grass roots plants.

The costs for the three sizes of MBG plants are presented in Table III-1. The variability is the result of site factors requiring either more earth moving or a more substantial foundation for the power house.

b) Building Block B1.31 Gasifier Equipment

The costs in this building block reflect the costs of the entrained flow gasifier, the coal feed and the oxygen plant.

The main cause of variability results from different industrial plants being members of different industrial consortiums. This allows a range of MBG plant sizes to be viable for industrial users. Other variation in equipment costs can result from MBG plants having fluctuating load requirements. Some MBG plants may need to store extra gasifiers to meet peak demands.

The distribution of equipment costs was obtained by calculating the costs for three different sizes of MBG plants. These costs were then aggregated to form the final cost distribution. The costs of the equipment for the three MBG plant sizes is contained in Table III-1.

c) Building Block C1.31 Coal Handling and Storage

The coal handling and storage costs were obtained from the Gilbert Associates paper.[1/] The low, medium and high cost cases are essentially the same as those for conventional coal steam ID. 8.11. These costs are presented in Table III-1.

d) Building Block D1.31 - Gas Cleanup System

The gas produced in all service sectors is assumed to be a "clean" gas with all tars, oils and sulfur removed. It is uneconomic for an MBG plant to supply two streams of gas, one dirty and one clean since this results in much duplication of the distribution system. The variability is caused by site difficulties requiring additional structural and foundation support. The costs are listed in Table III-1.

e) Building Block E1.31 - Gas Distribution System

The cost of the MBG distribution system represents a significant portion of the overall capital costs. The most volatile component of MBG transportation cost is the cost of the pipeline. These costs can vary erratically depending upon the pipe size, labor, type of terrain and number of obstructions (natural or manmade). For example the costs are higher in urban and suburban areas where streets have to be torn up and repaved, other underground pipes and cables cut or avoided at additional expense. Figure III-1 illustrates some of the variability present in pipeline costs. For each size pipe the highs, lows and a weighted average of pipeline costs reported each year to the Federal Power Commission are shown.

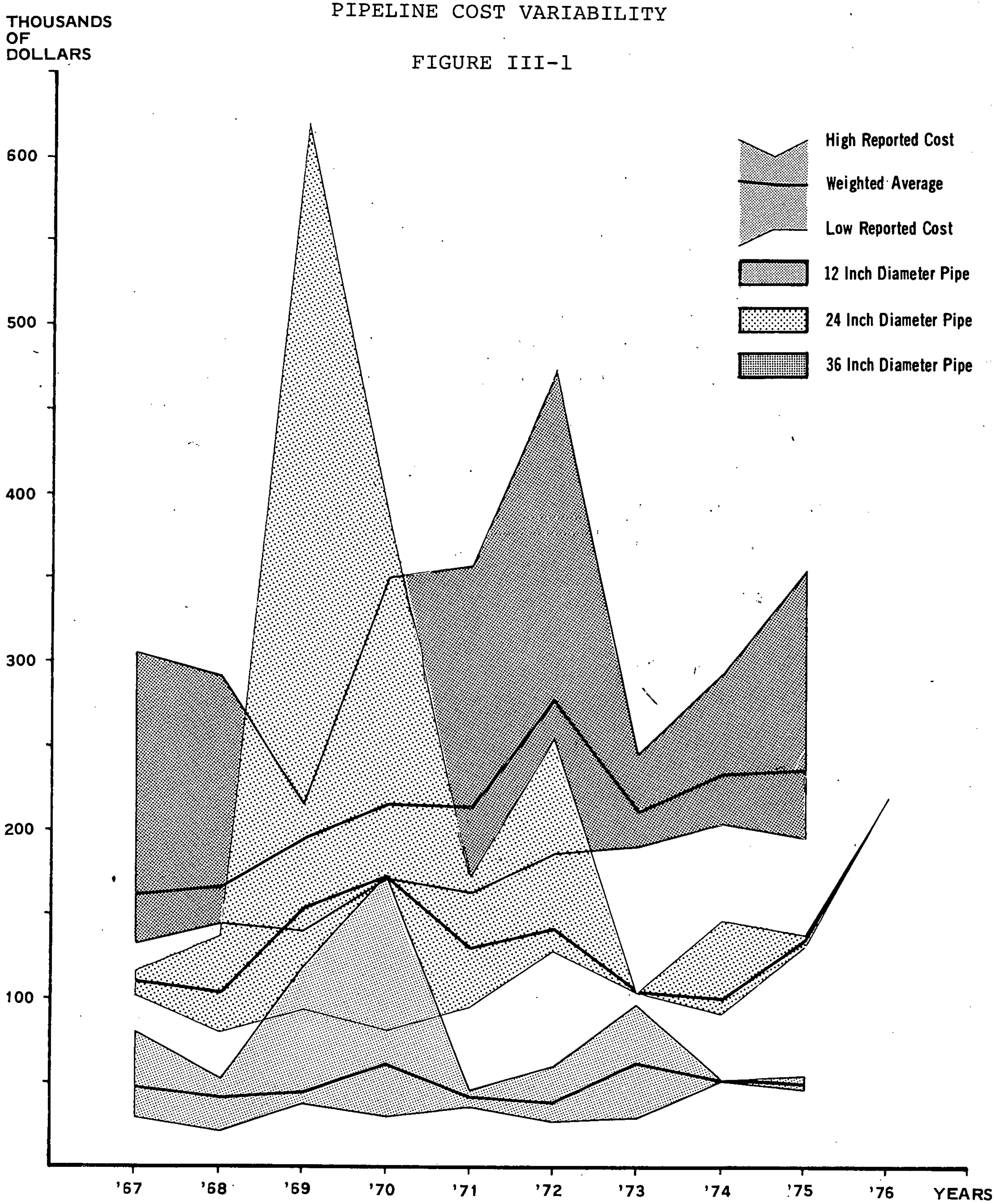
In addition to the pipeline, other significant costs are the right-of-way costs and compression costs. For a given size of pipe, the higher the pressure, the lower the velocity required to maintain a given energy throughput. While lower velocities create less frictional losses they can only be achieved at the expense of greater compression energy and/or larger pipe size. There is a three way trade-off between compression energy, pipe size and frictional losses that can only be optimized on a case by case basis.

The compression costs for MBG distribution are considerably higher than for natural gas due to MBG's lower heating value per standard cubic foot of gas. A centrifugal compressor is the probable compressor design resulting from the need to compress large volumes of MBG.

A separate distribution system was designed for each MBG plant size. For the 50 MMMBtu/day size the distribution system could serve an area approximately 15 miles in length and 10 miles in width. The system includes 20 miles of main line, 40 miles of branch line and is capable of serving 6 to 8 plants. The main line is 24 inch diameter pipe and the branch line is comprised of 30 miles of 12 inch pipe and 10 miles of 10 inch pipe. The costs and specifications for the pipelines was calculated from data made available by the Federal Power Commission. These costs are shown in Table III-2. The FPC includes the costs of obtaining rights of way in the pipeline cost. Typically rights of way cost between $2,000 and $4,000 per mile, although they are highly variable.

PIPELINE COST VARIABILITY

FIGURE III-1



BASED ON TRANSMISSION LINE COSTS REPORTED TO FPC BY FISCAL YEARS

In designing an MBG distribution system the length of the pipeline required is dependent upon the available rights-of-way. Often rights--of-way will be available only along roads or other existing pipelines. Straight routes between the MBG plant and the industrial users will rarely occur. Our analysis assumes approximately 1.4 miles of pipe required for every mile of direct distance between adjoining points on the pipeline.

The specifications for each distribution system are presented in Table III-2. The final costs of the distribution systems are presented in Table III-1.

The best case is calculated from the pipeline costs presented in Table III-2. They represent good conditions with little elevation changes or obstructions. The cost variability in the other two cases result from hilly terrain, rocky soil or other site difficulties.

TABLE III-2

MBG PIPELINE COSTS

Gas Composition:	CO-58.45%, $CO_{@}$ -8%, H_2 - 31.6%, N_2 - 1.2%
Pressure Drop:	10 psi/mile
Molecular Weight:	20.87 lb/mole
Initial pressure:	14.7
Initial temperature:	70°F
Final compressor pressure:	73.5 psia

Pipe Diameter inches	Quantity SCF/min	Heat Value MMBtu/min	Compressor Cost $/mi*	Compressor Cost $/MMBtu/mi	Pipeline Cost $/mi	Pipeline cost $/MMBtu/mi	Total cost $/mi
10"	9,670	2.9	$130,000	$44,800	$65,000	$22,413	$195,000
12"	13,693	4.1	$177,500	$43,300	$75,000	$18,257	$252,000
24"	74,133	22.2	$961,000	$43,288	$200,000	$8,992	$1,161,000
36"	205,800	61.7	$2,668,500	$43,250	$275,000	$4,454	$2,943,500

TABLE III-3

MBG DISTRIBUTIONS SYSTEMS

		main line pipe miles		branch line pipe miles		area serviced	
	MBG Plant Size	36 inch	24 inch	12 inch	10 inch	# of plants	miles
system #1	50 MMMBtu/day	0	20	30	10	6-8	8 x 16 miles^2
system #2	100 MMMBtu/day	0	40	40	30	8-12	12 x 24 miles^2
system #3	250 MMMBtu/day	25	25	50	30	9-14	20 x 30 miles^2

* Assumes one compressor for every five miles of pipe

TABLE III-1

MBG PRODUCTION AND DISTRIBUTION
Capital Costs (thousands of 1977 $'s)

	50 MMMBtu/day	100 MMMBtu/day	250 MMMBtu/day
1. Site Preparation, Power House and Utilities			
low cost	20,815	28,600	51,955
medium cost	22,428	30,817	55,982
high cost	29,507	35,551	64,703
2. Coal Feed, Gasifier and Oxygen Plant			
low cost	78,717	108,576	198,153
medium cost	--	--	--
high cost	--	--	--
3. Coal Handling and Storage			
low cost	5,805	9,408	20,217
medium cost	6,515	10,558	22,688
high cost	7,810	12,658	27,201
4. Gas Cleanup System			
low cost	14,686	20,473	36,966
medium cost	15,439	21,523	38,862
high cost	16,757	23,273	42,022
5. Distribution System			
low cost	34,800	62,000	121,100
medium cost	49,200	92,700	193,700
high cost	71,000	133,000	277,500

2. Allocation of Costs to Individual Users

The costs for the MBG plant and distribution system are presented in Table III-1. In allocating these costs to individual users it is assumed that each user is charged according to the proportion of total gas output they consume. The costs derived for each of the building blocks are for a user consuming 50 MMBtu/hr of medium Btu gas.

Early runs of the model indicated that the 50 MMBtu/day MBG plant was not economically competitive with the other energy technologies in our model. In constructing the building blocks only the 100 MMMBtu/day and 250 MMMBtu/day plant sizes were used.

The cost allocation scaler for the 100 MMMBtu/day plant is:

$$\frac{50 \times 10^6 \text{ Btu/hr}}{100 \times 10^9 \text{ Btu/day}} \quad \frac{24 \text{ hrs}}{1 \text{ day}} = .012$$

For the 250 MMMBtu/day plant the scaler is .0048. These two scalers are multiplied times the costs listed in Table III-1. With this adjustment, the site preparation and power house costs become:

Site Preparation, Power House and Utility
Costs allocated to a 50 MMBtu/hr user

	100 MMMBtu/day	250 MMMBtu/day
low cost	$343,200	$249,400
medium cost	$369,800	$268,700
high cost	$426,600	$310,600

TABLE III-4

MBG CAPITAL COSTS ALLOCATED TO A SINGLE 50 MMBtu/hr USER
(composite costs of the 100 MMBtu/day and 250 MMBtu/day
MBG plants)

A1.31 Site Preparation, Power House and Utilities

low cost	$249,000
medium cost	$311,000
high cost	$427,000

B1.31 Coal Fired, Gasifier and Oxygen Plant

low cost	$951,000
medium cost	$1,303,000
high cost	--

C1.31 Coal Handling and Storage

low cost	$97,000
medium cost	$113,000
high cost	$152,000

D1.31 Gas Cleanup System

low cost	$177,000
medium cost	$202,000
high cost	$1,279,000

E1.31 Distribution System

low cost	$582,000
medium cost	$930,000
high cost	$1,332,000

The determination of the frequency estimates for the MBG technologies is more speculative than for other ISTUM technologies. Since the MBG plants must be located in areas of high energy concentration their potential sites are limited. No information is available on the number of potential sites that could support a 100 MMBtu/day plant as opposed to a 250 MMBtu/day plant. We assumed that the frequency of occurence of the 100 MMBtu/day and 250 MMBtu/day was the same. Each of the cost cases was also assumed to occur with equal frequency. Based on these assumptions a composite distribution is constructed:

Building Block A1.31 - Site Preparation, Power House and Utilities
50 MMBtu/hr plant
(costs in thousands of 1977 $'s)

	frequency	capital cost
low cost	.33	249
medium cost	.50	311
high cost	.17	427

Note that the low and high costs for the combined cost set of costs allocated to a 50 MMBtu user for the 100 MMMBtu/day and 250 MMMBtu/day MBG plants are maintained. The same procedure is used to derive all the MBG production building blocks. The costs for all the MBG building blocks are listed in Table III-4.

Operating and maintenance costs are estimated as a percentage of capital costs. They are derived from O&M estimates made on comparable equipment in other technologies and information from the two Gilbert Associates papers.

MBG COMBUSTION COSTS AND SERVICE SECTOR APPLICATIONS

Once the production costs are specified by a set of building blocks, to obtain the overall MBG technology costs these blocks are then combined with the building blocks used to specify natural gas combustion in each service sector. This is the same procedure as was used for LBG.

GENERAL INFORMATION FOR FOSSIL ENERGY TECHNOLOGIES

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TECH ID	TECHNOLOGY NAME	YEAR AVAIL	FUELS USED	FUEL SHARE (1ST FUEL)	FUEL EFFECIENCY COMB USTN	FUEL EFFECIENCY TRAN SMIS	FUEL EFFECIENCY FINL USE	SIZE RANGE (MMBTU/HR) LO	SIZE RANGE (MMBTU/HR) HI	LOAD RANGE (HRS/YR) LO	LOAD RANGE (HRS/YR) HI	MAXIMUM FRACTION INCRE MENTL	MAXIMUM FRACTION RETRO FIT	MAXIMUM FRACTION CONSE RVATN
1.11	ATM, FLUID BED	1982	1	1.00	1.00	1.00	0.82	¯1	¯1	¯1	¯1	0.70	0.00	1.00
1.112	ATM, FLUID BED	1982	1	1.00	1.00	1.00	0.82	¯1	¯1	¯1	¯1	0.70	0.00	1.00
1.14	ATM, FLUID BED	1983	1	1.00	1.00	1.00	0.67	¯1	¯1	¯1	¯1	0.70	0.00	1.00
1.21	LOW BTU GAS	1980	1	1.00	0.90	0.82	0.82	¯1	¯1	¯1	¯1	0.50	0.00	1.00
1.212	LOW BTU GAS	1980	1	1.00	0.90	0.82	0.82	¯1	¯1	¯1	¯1	0.50	0.00	1.00
1.213	LOW BTU GAS	1982	1	1.00	0.90	0.82	0.67	¯1	¯1	¯1	¯1	0.70	0.00	1.00
1.214	LOW BTU GAS	1982	1	1.00	0.90	0.98	0.40	¯1	¯1	¯1	¯1	0.70	0.00	1.00
1.215	LOW BTU GAS	1982	1	1.00	0.90	0.98	0.33	¯1	¯1	¯1	¯1	0.70	0.00	1.00
1.216	LOW BTU GAS	1980	1	1.00	0.90	0.98	0.31	¯1	¯1	¯1	¯1	0.70	0.00	1.00
1.217	LOW BTU GAS	1982	1	1.00	0.90	0.98	0.33	40	600	¯1	¯1	0.70	0.00	1.00
1.219	LOW BTU GAS	1982	1	1.00	0.90	0.98	0.30	¯1	¯1	¯1	¯1	0.70	0.00	1.00
1.22	LOW BTU GAS	1982	1	1.00	0.90	0.82	0.36	40	600	¯1	¯1	0.70	0.00	1.00
1.23	LOW BTU GAS	1982	1	1.00	0.90	0.98	0.30	¯1	¯1	¯1	¯1	0.70	0.00	1.00
1.24	LOW BTU GAS	1982	1	1.00	0.90	0.98	0.67	¯1	¯1	¯1	¯1	0.50	0.00	1.00
1.26	LBG SELF GEN	1980	1	1.00	0.60	1.00	0.40	¯1	¯1	¯1	¯1	0.70	0.00	1.00
1.31	MEDIUM BTU GAS	1983	1	1.00	0.75	0.94	0.82	¯1	¯1	¯1	¯1	0.10	0.00	1.00
1.314	MEDIUM BTU GAS	1983	1	1.00	0.75	0.94	0.40	¯1	¯1	¯1	¯1	0.10	0.00	1.00
1.315	MEDIUM BTU GAS	1983	1	1.00	0.75	0.94	0.33	¯1	¯1	¯1	¯1	0.10	0.00	1.00
1.316	MEDIUM BTU GAS	1983	1	1.00	0.75	0.94	0.31	¯1	¯1	¯1	¯1	0.10	0.00	1.00
1.317	MEDIUM BTU GAS	1983	1	1.00	0.75	0.94	0.33	¯1	¯1	¯1	¯1	0.10	0.00	1.00
1.319	MEDIUM BTU GAS	1983	1	1.00	0.75	0.94	0.31	¯1	¯1	¯1	¯1	0.10	0.00	1.00
1.32	MEDIUM BTU GAS	1983	1	1.00	0.75	0.94	0.36	40	600	¯1	¯1	0.10	0.00	1.00
1.33	MEDIUM BTU GAS	1983	1	1.00	0.75	0.94	0.30	¯1	¯1	¯1	¯1	0.10	0.00	1.00
1.34	MEDIUM BTU GAS	1983	1	1.00	0.75	0.94	0.67	¯1	¯1	¯1	¯1	0.04	0.00	1.00
1.45	LBG SELF GEN	1980	1	1.00	0.60	1.00	0.40	¯1	¯1	¯1	¯1	0.70	0.00	1.00

GENERAL INFORMATION FOR FOSSIL ENERGY TECHNOLOGIES continued

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TECH ID	TECHNOLOGY NAME	SERV SECT	DATA QUALITY MAX FRAC	COST	ENER SAVE	ACCELER	CONST PER (YRS)	PHYS LIFE (YRS)	DOE ACCEL (YRS)	LAST UPDATED
1.11	ATM. FLUID BED	1	B	B		C	2.0	25	3	MAR 12, 1978 1:39:54 PM
1.112	ATM. FLUID BED	12	B	B		C	1.0	25	3	MAR 19, 1978 3:50:06 PM
1.14	ATM. FLUID BED	4	C	C		C	1.5	25	3	MAR 17, 1978 7:46:38 PM
1.21	LOW BTU GAS	1	B	B		C	2.5	25	2	APR 6, 1978 2:50:24 PM
1.212	LOW BTU GAS	12	B	B		C	2.5	25	2	APR 7, 1978 12:24:03 PM
1.213	LOW BTU GAS	13	B	B		C	2.0	25	3	APR 7, 1978 12:24:09 PM
1.214	LOW BTU GAS	14	B	B		C	2.0	25	3	APR 6, 1978 9:25:28 AM
1.215	LOW BTU GAS	15	B	B		C	2.0	10	3	APR 6, 1978 9:25:35 AM
1.216	LOW BTU GAS	16	B	B		C	2.0	25	2	APR 6, 1978 9:25:48 AM
1.217	LOW BTU GAS	17	B	B		C	2.0	25	3	APR 6, 1978 9:26:00 AM
1.219	LOW BTU GAS	19	B	B		C	2.0	25	3	APR 6, 1978 9:26:09 AM
1.22	LOW BTU GAS	2	B	B		C	2.0	25	3	APR 6, 1978 9:25:01 AM
1.23	LOW BTU GAS	3	B	B		C	2.0	25	3	APR 6, 1978 9:25:09 AM
1.24	LOW BTU GAS	4	B	B		C	2.0	25	3	APR 6, 1978 2:54:00 PM
1.26	LBG SELF GEN	6	B	B		C	2.5	25	3	MAR 17, 1978 6:55:40 AM
1.31	MEDIUM BTU GAS	1	D	C		C	3.0	25	3	MAR 28, 1978 11:19:57 AM
1.314	MEDIUM BTU GAS	14	D	C		C	3.0	25	3	MAR 17, 1978 7:48:57 PM
1.315	MEDIUM BTU GAS	15	D	C		C	3.0	25	3	MAR 17, 1978 7:48:33 PM
1.316	MEDIUM BTU GAS	16	D	C		C	3.0	25	3	MAR 17, 1978 7:40:11 PM
1.317	MEDIUM BTU GAS	17	D	C		C	3.0	25	3	MAR 17, 1978 7:34:07 PM
1.319	MEDIUM BTU GAS	19	D	C		C	3.0	25	3	MAR 17, 1978 7:36:14 PM
1.32	MEDIUM BTU GAS	2	D	C		C	3.0	25	3	MAR 17, 1978 9:19:45 PM
1.33	MEDIUM BTU GAS	3	D	C		C	3.0	25	3	MAR 17, 1978 9:22:53 PM
1.34	MEDIUM BTU GAS	4	D	C		C	3.0	25	3	MAR 17, 1978 7:42:16 PM
1.45	LBG SELF GEN	5	B	B		C	2.0	25	3	MAR 17, 1978 7:06:52 AM

GENERAL INFORMATION FOR FOSSIL ENERGY TECHNOLOGIES continued

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1.11	ATM, FLUID BED	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.112	ATM, FLUID BED	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.14	ATM, FLUID BED	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.21	LOW BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.212	LOW BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.213	LOW BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.214	LOW BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.215	LOW BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.216	LOW BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.217	LOW BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.219	LOW BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.22	LOW BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.23	LOW BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.24	LOW BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.26	LBG SELF GEN									1					1	1	1										
1.31	MEDIUM BTU GAS	1								1	1			1	1	1	1	1									
1.314	MEDIUM BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.315	MEDIUM BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.316	MEDIUM BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.317	MEDIUM BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.319	MEDIUM BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.32	MEDIUM BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.33	MEDIUM BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.34	MEDIUM BTU GAS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.45	LBG SELF GEN	1		1	1	1	1	1	1	1	1	1		1				1	1	1	1	1	1	1	1	1	1

FOSSIL ENERGY TECHNOLOGY SPECIFICATIONS

BUILDING BLOCK COEFFICIENTS
PRINTED APR 7, 1978 5:29:28 PM

TECH ID 1.11
UPDATED APR 4, 1978 3:11:11 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.11	0.83	0.50	1.95
B 1.11	1.00	0.64	1.79
C 8.11	0.83	0.75	2.66
D 8.11	0.83	0.21	0.67
E 8.11	0.83	0.68	1.99
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 1.112
UPDATED APR 7, 1978 11:47:53 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.11	0.83	0.28	0.90
B 1.11	1.00	0.41	1.00
C 8.11	0.83	0.43	1.30
D 8.11	0.83	0.13	0.35
E 8.11	0.83	0.42	1.08
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 1.14
UPDATED MAR 17, 1978 8:53:

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 1.14	1.00	1.00
C 8.14	1.00	1.20
B 1.14	1.00	1.00
E 8.14	1.00	1.00
H 8.11	1.00	1.00
I 8.11	1.00	1.00

TECH ID 1.21
UPDATED APR 7, 1978 12:30:10 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.22	1.00	0.76	1.91
B 1.22	1.00	0.66	2.72
C 1.22	1.00	0.69	1.91
D 8.11	0.83	0.61	1.91
E 1.22	1.00	0.74	2.07
A 8.11	0.23	0.57	2.10
B 8.11	0.29	0.53	2.30
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 1.212
UPDATED APR 7, 1978 12:30:10 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.22	1.00	0.57	1.25
B 1.22	1.00	0.42	1.42
C 1.22	1.00	0.46	1.36
D 8.11	0.83	0.33	1.00
E 1.22	1.00	0.53	1.29
A 8.11	0.23	0.32	1.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
B 8.11	0.29	0.28	1.00

TECH ID 1.213
UPDATED APR 6, 1978 4:31:2

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 1.22	1.00	2.37
B 1.22	1.00	3.79
C 1.22	1.00	3.26
D 1.22	1.00	2.64
E 1.22	1.00	2.64
A 8.34	1.00	1.00
H 8.11	1.00	1.00
I 8.11	1.00	1.00

TECH ID 1.214
UPDATED APR 6, 1978 4:39:0

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 1.22	1.00	1.01
B 1.22	1.00	1.02
C 1.22	1.00	1.01
E 1.22	1.00	1.01
A 8.314	1.00	1.00
H 8.11	1.00	1.00
I 8.11	1.00	1.00

TECH ID 1.215
UPDATED APR 6, 1978 4:39:00 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.22	1.00	1.16	1.51
B 1.22	1.00	1.25	1.89
C 1.22	1.00	1.22	1.76
E 1.22	1.00	1.18	1.59
A 8.315	1.00	1.00	1.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 1.216
UPDATED APR 6, 1978 4:39:0

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 1.22	1.00	0.62
B 1.22	1.00	0.47
C 1.22	1.00	0.43
E 1.22	1.00	0.58
A 8.316	1.00	1.00
H 8.11	1.00	1.00
I 8.11	1.00	1.00

FOSSIL ENERGY TECHNOLOGY SPECIFICATIONS continued

TECH ID 1.217
UPDATED APR 6, 1978 4:39:00 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.22	1.00	0.18	1.18
B 1.22	1.00	0.07	1.28
C 1.22	1.00	0.09	1.25
E 1.22	1.00	0.15	1.20
A 8.317	1.00	1.00	0.00
F 8.317	1.00	0.00	1.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 1.219
UPDATED APR 6, 1978 4:39:00 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.22	1.00	0.27	1.50
B 1.22	1.00	0.13	1.87
C 1.22	1.00	0.17	1.74
E 1.22	1.00	0.23	1.58
A 8.319	1.00	1.00	0.00
F 8.319	1.00	0.00	1.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 1.22
UPDATED APR 6, 1978 4:47:32 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.22	1.00	0.54	1.34
B 1.22	1.00	0.38	1.59
C 1.22	1.00	0.43	1.50
D 1.22	1.00	0.50	1.40
E 1.22	1.00	0.50	1.40
A 8.32	1.00	0.00	1.00
A 8.99	1.00	1.00	0.00
B 8.99	1.00	1.00	0.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 1.23
UPDATED APR 6, 1978 4:47:32 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.22	1.00	0.54	1.34
B 1.22	1.00	0.38	1.59
C 1.22	1.00	0.43	1.50
E 1.22	1.00	0.50	1.40
A 8.33	1.00	1.00	4.97
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 1.24
UPDATED APR 6, 1978 4:47:3

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 1.22	1.00	1.90
B 1.22	1.00	2.69
C 1.22	1.00	2.40
E 1.22	1.00	2.05
A 8.34	1.00	1.00
H 8.11	1.00	1.00
I 8.11	1.00	1.00

TECH ID 1.26
UPDATED APR 5, 1978 5:11:5

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.11	1.01	6.90
B 1.21	1.00	12.50
C 8.11	0.91	7.00
D 8.11	1.00	8.00
E 8.11	1.10	8.00
H 8.11	1.00	1.00
I 8.11	1.00	1.00
C 5.71	2.40	1.00
B 8.16	1.00	1.00

TECH ID 1.31
UPDATED MAR 16, 1978 9:48:19 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.31	2.00	0.50	2.50
B 1.31	2.00	0.50	2.50
C 1.31	2.00	0.50	2.50
D 1.31	2.00	0.50	2.50
E 1.31	2.00	0.50	2.50
A 8.11	0.46	0.64	2.10
B 8.11	0.29	0.64	2.30
E 8.11	0.60	0.64	2.25
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 1.314
UPDATED APR 7, 1978 10:59:

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.314	1.00	1.00
C 8.316	1.00	1.50
H 8.11	1.00	1.00
I 8.11	1.00	1.00
A 1.31	2.00	1.00
B 1.31	2.00	1.00
C 1.31	2.00	1.00
D 1.31	2.00	1.00
E 1.31	2.00	1.00

TECH ID 1.315
UPDATED APR 7, 1978 10:59:55 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.315	1.00	1.00	1.00
C 8.316	1.00	1.70	2.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
A 1.31	2.00	1.26	2.02
B 1.31	2.00	1.26	2.02
C 1.31	2.00	1.26	2.02
D 1.31	2.00	1.26	2.02
E 1.31	2.00	1.26	2.02

TECH ID 1.316
UPDATED APR 7, 1978 11:56:

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 1.31	2.00	0.42
C 1.31	2.00	0.42
D 1.31	2.00	0.42
E 1.31	2.00	0.42
A 8.316	1.00	1.00
C 8.316	1.00	1.00
H 8.11	1.00	1.00
I 8.11	1.00	1.00

TECH ID 1.317
UPDATED APR 7, 1978 10:59:55 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.317	1.00	1.00	0.00
F 8.317	1.00	0.00	1.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
A 1.31	2.00	0.05	4.00
B 1.31	2.00	0.05	4.00
C 1.31	2.00	0.05	4.00
D 1.31	2.00	0.05	4.00
E 1.31	2.00	0.05	4.00
C 8.316	1.00	0.33	3.00

TECH ID 1.319
UPDATED APR 7, 1978 11:56:24 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.319	1.00	1.00	0.00
F 8.319	1.00	0.00	1.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
A 1.31	2.00	0.10	2.00
B 1.31	2.00	0.10	2.00
D 1.31	2.00	0.10	2.00
C 1.31	2.00	0.10	2.00
C 8.216	1.00	0.35	3.53

TECH ID 1.32
UPDATED APR 7, 1978 11:11:33 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.31	2.00	0.23	1.13
B 1.31	2.00	0.23	1.13
C 1.31	2.00	0.23	1.13
D 1.31	2.00	0.23	1.13
E 1.31	2.00	0.23	1.13
A 8.32	1.00	0.00	1.00
C 8.316	1.00	0.00	1.00
A 8.99	1.00	1.00	0.00
B 8.99	1.00	1.00	0.00
E 8.99	1.00	1.00	0.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 1.33
UPDATED APR 7, 1978 11:11:33 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.31	2.00	0.27	1.37
B 1.31	2.00	0.27	1.37
C 1.31	2.00	0.27	1.37
D 1.31	2.00	0.27	1.37
E 1.31	2.00	0.27	1.37
A 8.33	1.00	1.00	4.97
C 8.316	1.00	1.00	5.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 1.34
UPDATED MAR 22, 1978 5:10:

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.34	1.00	1.00
C 8.34	1.00	1.00
E 8.14	1.00	0.31
H 8.11	0.90	1.00
I 8.11	1.00	1.00
A 1.31	2.00	3.73
B 1.31	2.00	3.73
C 1.31	2.00	3.73
D 1.31	2.00	3.73
E 1.31	2.00	3.73

TECH ID 1.45
UPDATED APR 4, 1978 2:16:16 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.11	1.01	0.56	1.69
B 1.21	1.05	0.56	2.25
C 8.11	0.91	0.56	1.70
D 1.21	1.00	0.56	1.80
E 8.11	1.10	0.56	1.80
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
C 5.71	2.50	0.23	1.00
B 8.15	1.00	0.35	1.00

BUILDING BLOCKS
PRINTED APR 7, 1978 5:36:55 PM

ID: A 1.14
NAME: AFB IN IND HT PRIM SYS
LAST UPDATED MAR 21, 1978 10:27:38 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	11,137.000
0.600	14,000.000
0.100	21,477.000
0.000	0.000

ID: A 1.22
NAME: SITE PREP
LAST UPDATED APR 6, 1978 6:30:32 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.03
FREQUENCY AND COST DATA:

0.400	463.000
0.400	476.000
0.200	540.000
0.000	0.000

ID: A 1.31
NAME: SITE PREP CONSTR UTIL
LAST UPDATED APR 6, 1978 2:43:08 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE S
FRACTION OF COSTS FOR O+M: 0.01
FREQUENCY AND COST DATA:

0.330	249.000
0.500	311.000
0.170	427.000
0.000	0.000

ID: A 8.11
NAME: SITE PREP
LAST UPDATED MAR 12, 1978 6:30:33 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.03
FREQUENCY AND COST DATA:

0.500	541.000
0.400	823.000
0.100	1,761.000
0.000	0.000

FOSSIL ENERGY BUILDING BLOCKS

ID: A 8.314
NAME: PRIMARY SYSTEM
LAST UPDATED MAR 21, 1978 10:15:38 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 40
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	500.000
0.550	527.000
0.150	703.000
0.000	0.000

ID: A 8.315
NAME: PRIM SYS GAS GLASS MLTG BATH
LAST UPDATED MAR 21, 1978 10:11:12 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 41.6
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	630.000
0.600	663.000
0.100	884.000
0.000	0.000

ID: A 8.316
NAME: PRIMARY SYSTEM CONVENTIONAL GAS
LAST UPDATED MAR 21, 1978 10:05:57 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 13.1
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	211.000
0.600	223.000
0.100	297.000
0.000	0.000

ID: A 8.317
NAME: PRIMARY SYSTEM BLAST FURN STIOVE
LAST UPDATED MAR 21, 1978 10:03:43 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 1.6
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.400	24.000
0.500	25.000
0.100	33.000
0.000	0.000

ID: A 8.319
NAME: PRIMARY SYSTEM (SMALL SIZE CLASS)
LAST UPDATED MAR 21, 1978 10:02:01 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 3
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.400	50.000
0.400	71.000
0.200	114.000
0.000	0.000

ID: A 8.32
NAME: DIRECT GAS PRIMARY SYSTEM
LAST UPDATED MAR 21, 1978 10:19:11 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	695.000
0.500	772.000
0.200	849.000
0.000	0.000

ID: A 8.33
NAME: NEW DIRECT GAS
LAST UPDATED MAR 21, 1978 10:20:56 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 10
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	167.000
0.500	238.000
0.200	381.000
0.000	0.000

ID: A 8.34
NAME: PRIM SYS ATM DIST AND CAT REF
LAST UPDATED MAR 21, 1978 10:29:49 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	1,865.000
0.600	1,963.000
0.100	2,617.000
0.000	0.000

FOSSIL ENERGY BUILDING BLOCKS continued

ID: A 8.99
NAME: SITE PREP
LAST UPDATED MAR 17, 1978 10:22:27 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 10
TYPE S
FRACTION OF COSTS FOR O+M: 0.01
FREQUENCY AND COST DATA:

0.300	5.000
0.600	20.000
0.100	60.000
0.000	0.000

ID: B 1.11
NAME: ATMOSPHERIC FLUID BED BOILER
LAST UPDATED MAR 12, 1978 6:38:46 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.12
FREQUENCY AND COST DATA:

0.300	2,800.000
0.500	3,100.000
0.200	3,900.000
0.000	0.000

ID: B 1.14
NAME: PARTICULATE CONTROL
LAST UPDATED MAR 17, 1978 9:01:05 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

1.000	1,220.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: B 1.21
NAME: LBG EQUIPMENT
LAST UPDATED MAR 22, 1978 1:52:44 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.12
FREQUENCY AND COST DATA:

0.350	916.000
0.550	1,679.000
0.100	2,239.000
0.000	0.000

FOSSIL ENERGY BUILDING BLOCKS continued

ID: B 1.22
NAME: LBG EQUIPMENT
LAST UPDATED APR 6, 1978 2:34:09 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	350.000
0.500	930.000
0.200	1,312.000
0.000	0.000

ID: B 1.31
NAME: EQUIPMENT COSTY
LAST UPDATED APR 6, 1978 2:43:24 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE S
FRACTION OF COSTS FOR O+M: 0.12
FREQUENCY AND COST DATA:

0.500	951.000
0.500	1,303.000
0.000	0.000
0.000	0.000

ID: B 8.11
NAME: BOILER EQUIPMENT (GENERAL)
LAST UPDATED MAR 12, 1978 6:54:53 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.115
FREQUENCY AND COST DATA:

0.350	1,500.000
0.550	2,100.000
0.100	2,520.000
0.000	0.000

ID: B 8.15
NAME: EQUIPMENT TURBINE
LAST UPDATED MAR 22, 1978 1:25:55 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

1.000	5,533.500
0.000	0.000
0.000	0.000
0.000	0.000

FOSSIL ENERGY BUILDING BLOCKS continued

ID: B 8.16
NAME: EQUIPMENT TURBINE
LAST UPDATED MAR 24, 1978 1:45:22 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 600
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

1.000	16,401.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: B 8.99
NAME: EQUIP COST
LAST UPDATED MAR 17, 1978 10:23:08 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 10
TYPE S
FRACTION OF COSTS FOR O+M: 0.08
FREQUENCY AND COST DATA:

0.200	36.000
0.500	47.000
0.300	58.000
0.000	0.000

ID: C 1.22
NAME: LBG COAL HANDLING
LAST UPDATED APR 6, 1978 2:35:26 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.12
FREQUENCY AND COST DATA:

0.300	332.000
0.400	515.000
0.300	706.000
0.000	0.000

ID: C 1.31
NAME: COAL HANDLING
LAST UPDATED APR 6, 1978 6:30:38 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE S
FRACTION OF COSTS FOR O+M: 0.12
FREQUENCY AND COST DATA:

0.330	97.000
0.500	113.000
0.170	152.000
0.000	0.000

FOSSIL ENERGY BUILDING BLOCKS continued

ID: C 5.71
NAME: DEMAND CHARGE
LAST UPDATED APR 7, 1978 3:53:57 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE L
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.030	1.500
0.940	3.580
0.030	5.670
0.000	0.000

ID: C 8.11
NAME: FUEL HANDLING
LAST UPDATED MAR 13, 1978 3:43:03 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.12
FREQUENCY AND COST DATA:

1.000	467.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: C 8.14
NAME: FUEL HDLG COaL INC PULV
LAST UPDATED MAR 14, 1978 3:41:54 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	1,100.000
0.400	1,236.000
0.300	1,848.000
0.000	0.000

ID: C 8.216
NAME: FUEL HANDLING (OIL)
LAST UPDATED MAR 18, 1978 6:15:06 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 13.1
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

0.500	77.000
0.500	92.000
0.000	0.000
0.000	0.000

ID: C 8.316
NAME: FUEL HANDLING GAS
LAST UPDATED MAR 14, 1978 3:11:48 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 13.1
TYPE S
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

1.000	6.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: C 8.34
NAME: FUEL HANDLING GAS
LAST UPDATED MAR 14, 1978 3:45:52 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE S
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

1.000	17.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: D 1.21
NAME: ENVIRONMENTAL COSTS
LAST UPDATED MAR 15, 1978 12:07:04 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.11
FREQUENCY AND COST DATA:

0.500	2,122.000
0.400	2,375.000
0.100	2,710.000
0.000	0.000

ID: D 1.22
NAME: GL CLNP INC SO2 REM WSTE REM
LAST UPDATED APR 6, 1978 2:37:11 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.300	2,122.000
0.400	2,375.000
0.300	2,710.000
0.000	0.000

ID: D 1.31
NAME: ENVIRONMENTAL CONTROLS
LAST UPDATED APR 6, 1978 2:44:23 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE S
FRACTION OF COSTS FOR O+M: 0.11
FREQUENCY AND COST DATA:

0.330	177.000
0.500	202.000
0.170	279.000
0.000	0.000

ID: D 8.11
NAME: ENVIRONMENTAL CONTROL SYSTEM
LAST UPDATED MAR 12, 1978 6:57:38 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

1.000	2,340.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: E 1.22
NAME: LBG AUXILIARIES
LAST UPDATED APR 6, 1978 2:36:16 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.400	141.000
0.400	154.000
0.200	179.000
0.000	0.000

ID: E 1.31
NAME: DISTRIBUTION SUSTEM
LAST UPDATED APR 6, 1978 2:44:40 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE S
FRACTION OF COSTS FOR O+M: 0.08
FREQUENCY AND COST DATA:

0.300	582.000
0.400	930.000
0.300	1,332.000
0.000	0.000

ID: E 8.11
NAME: FEEDWATER SYSTEM AND UTILITIES
LAST UPDATED MAR 12, 1978 7:01:07 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.07
FREQUENCY AND COST DATA:

0.200	210.000
0.500	260.000
0.300	660.000
0.000	0.000

ID: E 8.14
NAME: UTILITIES
LAST UPDATED MAR 17, 1978 4:05:11 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE S
FRACTION OF COSTS FOR O+M: 0.06
FREQUENCY AND COST DATA:

0.500	2,321.000
0.400	2,785.000
0.100	3,100.000
0.000	0.000

ID: E 8.99
NAME: UTILITIES
LAST UPDATED MAR 17, 1978 10:23:41 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 10
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

1.000	2.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: F 8.317
NAME: PRIM SYS BLST FURN HYRCAR INJ
LAST UPDATED MAR 22, 1978 7:50:20 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 133
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.400	2,015.000
0.500	2,121.000
0.100	2,828.000
0.000	0.000

FOSSIL ENERGY BUILDING BLOCKS continued

ID: F 8.319
NAME: PRIM SYS LARGE SIZE
LAST UPDATED MAR 22, 1978 7:49:25 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 60
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.400	1,000.000
0.400	1,250.000
0.200	1,750.000
0.000	0.000

ID: H 8.11
NAME: INDIRECT CAPITAL COSTS (ENGIN, CONTIN)
LAST UPDATED MAR 12, 1978 7:08:23 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 0
TYPE M
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.550	1.300
0.350	1.400
0.100	1.500
0.000	1.650

ID: I 8.11
NAME: CONSTRUCTION INDICES
LAST UPDATED MAR 12, 1978 7:09:36 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 0
TYPE M
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.400	0.870
0.400	0.970
0.200	1.070
0.000	1.250

PROGRAM EXITED

CHAPTER IV

COGENERATION AND SELF-GENERATION TECHNOLOGIES

A. Introduction

This section of the technology appendix documents the manner in which the cost data for the cogeneration and self-generation technologies in ISTUM were determined and modeled. The section is organized by service sector, describing the costs of cogeneration technologies in the steam, machine drive, and electrolytic service sectors. Each technology competing within a service sector is discussed according to each of its cost components.

Cogeneration technologies are unique for two reasons:

1. These technologies produce both steam and electricity. Thus the ISTUM model logic was modified to have these technologies compete in one service sector with feedback to or from another service sector (see Vol. I, chapter II.E.4).

2. These technologies require demand charges which are annual costs of reserving utility capacity to insure against in-plant generation failures. These costs are annual costs independent of capital costs but dependent on load factors. Thus the costs could not be entered as fuel costs or capital costs. Instead the costs were entered on a dollar per MMBtu/hr basis which considered load factors for the conversion to dollars per MMBtu.

Self-generation technologies are categorized according to whether or not they conserve energy (relative to electric utilities). Thus coal-fired self generation is considered a non-conserving technology since its efficiency approximates that of a utility. A diesel engine - organic rankine cycle system (ORCS) on the other hand conserves energy relative to a utility given since the ORCS recovers the waste heat from the diesel and converts it to electricity.

B. Steam Service Sector

1. Technology Name: Diesel Engine with Waste Heat Boiler-Export

   Technology I.D.: 5.41

BUILDING BLOCK DATA

a. Building Block-A5.71 Site Preparation

Site preparation for this technology was assumed equal to that of a coal boiler.

b. Building Block-B5.41 Equipment Costs

The equipment costs are the sum of the capital costs of the diesel engine and the waste heat boiler. The waste heat boiler costs $10/lb/hr installed. Producing 1250 Btu/lb, the boiler costs $2,000,000 to produce 250 MMBtu/hr. The total system produces electricity at a 1.05 ratio to steam - thus, the diesel engine is generating 262.5 MMBtu/hr. At $300 kW, the engine costs $23,080,304 to produce 262.5 MMBtu/hr. Total costs approximate $25,000,000. Industry interviews revealed O&M costs to approximate 5 percent of capital costs. Since the capital costs for this system are linear, the scale down factor, from 100 MMBtu/hr to 20 MMBtu/hr, was 0.20.

c. Building Block-C5.71 Demand Charge

The demand charge for a 100 MMBtu/hr (29,308.3 kW) electricity demand will vary by roughly the same amount as electricity prices vary. After studying several rate structures, Monongahela's appeared to be the mean structure and is presented below:

Monthly Charge

$11,877	⟶	first 2700 kW
$3.43/kW	⟶	next 12,600 kW
$3.09/kW	⟶	all additional

The demand charge calculated to $1.29 million which is entered as $5,160 per million Btu per hour of steam demand At 20 MMBtu/hr., the demand charge equals $272,630 which approximates a .23 scale down factor. The distribution around the mean was calculated by using DRI's standard deviation for electricity prices. Since electricity prices were shown to approximate a 1.50 standard deviation, demand charges, which are roughly half of electricity prices, were assumed to have a .75 standard deviation. Moving two standard deviations away from the mean, roughly 94 percent of the distribution could be accounted for. Thus, a 3 percent frequency distribution was associated with values for two standard deviations away on each side.

d. Building Block-H8.11 Feedwater Costs

The waste heat boiler has feedwater costs equal to that of a coal fired boiler. Thus, the relevant costs were taken from Technology 8.11 as shown.

e. Building Block-H8.11 Indirect Capital Costs

Derived from Technology 8.11.

f. Building Block-I8.11

Derived from Technology 8.11.

GENERAL DATA

a. Year Available - it was assumed that the ability to export electricity would not exist until 1979.

b. Fuels Used - ISTUM is modeled to consider the electricity credit as a negative consumption of electricity - thus the two fuels consumed are oil and electricity.

c. Fuel Share - the "efficiency factor" for electricity generation was actually a factor that converts the electricity price into an electricity credit per MMBtu of steam demand. For the export case, the following variables must be identified:

(1) Ratio of Electricity to Steam Demand - .4
(2) Ratio of Electricity to Steam Supply - 1.05
(3) Ratio of Exports to Steam Demand - .65 ((2)-(1))
(4) Ratio of Export Value to Electricity Purchase Price - (.60)

Total Value of Electricity Production

((3) x (4)) + (1)) x Electricity Price ⟶ .79 (Electricity Price)

The negative inverse of the above was entered into ISTUM. The fuel share algorithm was modified to take account of negative efficiencies given a fuel share equation of:

$$\text{fuel share} = 1 - e/d$$

where e = the efficiency of this technology
d = the electricity efficiency factor

a value of 1.3 was determined.

d. Service Sector - this technology generates both steam and electricity and thus could conceivably compete in either of these sectors. Because the steam sector must be run before the machine drive sector to calculate the maximum market fractions for steam topping cogeneration systems, this technology was entered as a steam generating technology credited with electricity production.

e. DOE Acceleration - it was assumed that DOE participation could enhance the possibility of exporting electricity to utilities by two years.

2. Technology Name: Diesel Engine with Waste Heat Boiler No Export

Technology I.D.: 5.51

BUILDING BLOCK DATA

a. Building Block-A5.71 Site Preparation

Site preparation for oil-fired conventional boiler plus diesel engine and waste heat boiler assumed equal to that of a coal-fired boiler of the same steam rating.

b. Building Block-B5.51 Equipment Costs

This block represents the costs for a diesel engine producing 100 MMBtu/hr. of electricity and a waste heat boiler producing 95 MMBtu/hr of steam (the ratio of electricity to steam production for this system is 1.05). Using the costs described under Block I.D.# B5.41, the diesel engine will cost $8.8 million, the waste heat boiler $.8 million, the total approximating $9,683,000.

c. Building Block-C5.71 Demand Charge

The demand charge is the same as that for Technology 5.41 since the same amount of electricity consumed in-house must be supplied by the utility in case of turbine shut-down or breakdown.

d. Building Blocks-B8.11, C8.11, D8.11, #8.11, H8.11, I8.11 Boiler Costs

These costs are the costs for a full 250 MMBtu/hr oil-fired boiler. While the boiler will have excess capacity most of the time, the full-sized boiler, similar to the demand charge, must be present in case of engine or waste heat boiler breakdown.

GENERAL DATA

a. Year Available - the technology is presently available

b. Fuels Used - see Tech 5.41

c. Fuel Share - see Tech 5.41

d. Fuel Efficiency - the fuel efficiency is the weighted average efficiency of this technology and a back up conventional oil-fired boiler. The former is .38, the latter .82 - the former provides 38 percent of the steam, the latter 62 percent. The weighted average efficiency is 57 percent.

e. Service Sector - see Tech 5.41

f. DOE Acceleration - certain developments in research in improving the reliability of diesel engines could accelerate market penetration.

3. Technology Name: Gas Turbine with Waste Heat Boiler - Export
Technology I.D.: 5.61

BUILDING BLOCK DATA

a. Building Block-A5.71 Site Preparation

These costs are assumed equal to that of a coal fired boiler.

b. Building Block-B5.61 Site Preparation

The gas turbine costs $200/kW, the waste heat boiler $10/lb/hr (at 1250 Btu/lb). The system's electricity to steam supply ratio is .819, thus producing 205 MMBtu/hr of electricity and 250 MMBtu/hr of steam. The costs for the gas turbine and waste heat boiler respectively are $11.9 million and $2 million, approximating $13.9 million for the entire system. Again, costs are linear, effecting a .2 scale down factor.

c. Building Block-C5.71 Demand Charge

The demand charge calculation is the same as described above.

d. Building Block-E8.11 Feedwater Costs

These costs represent the feedwater costs for the waste heat boiler, assumed equal to those of a coal-fired boiler.

e. Building Block-H8.11, I8.11 Indirect Capital Costs

These are assumed equal to those of a coal-fired boiler.

GENERAL DATA

a. Year Available - see Tech 5.41

b. Fuels Used - see Tech 5.41

c. Fuel Share - see Tech 5.41

d. Service Sector - see Tech 5.41

e. DOE Acceleration - see Tech 5.41

4. Technology Name: Gas Turbine with Waste Heat Boiler - No Export
Technology I.D.: 5.71

BUILDING BLOCK DATA

a. Building Block-A8.11 Site Preparation

The gas turbine and waste heat boiler are assumed to require the same site preparation as that of an equal steam rated coal-fired boiler.

b. Building Block-B5.71 Equipment Costs

The gas turbine will produce 100 MMBtu/hr, the waste heat boiler 122 MMBtu/hr. At the costs mentioned above, the gas turbine will cost $5.9 million, the waste heat boiler $.95 million, totalling $6.85 million. The scale down factor is 0.20 since the costs are linear.

c. Building Block-C5.71 Demand Charges

These are the same as for technologies 5.41, 5.51 and 5.61 since electricity demand fulfilled is assumed the same.

d. Building Block-B8.11, C8.11, D8.11, E8.11, H8.11, I8.11 Oil-fired Costs

Similar to Technology 5.51, these costs are for fulfilling the remaining steam demand and for backing up the waste heat boiler when it is not operating.

GENERAL DATA

See Technology 5.51 for descriptions of all data.

C. Machine Drive Service Sector

1. Cogeneration

a. Technology Name: AFB Topping Cogeneration
Technology I.D.: 1.15

BUILDING BLOCK

1. Building Block-A1.15 Equipment Costs

Turbine supplying the 100 MMBtu/hr. size range are assumed to be fed from a distribution of boilers as follows:

Distribution of Boilers Feeding Turbines
for Steam Topping

Size	Incremental Boiler Cost	Frequency
250 MMBtu/hr	$430,000	.85
600 MMBtu/hr	$2,000,000	.15

Turbine sizes are respectively 10 MMBtu/hr and 60 MMBtu/hr and cost $714,300 and $2,266,875. O&M costs are $100,000/yr. plus one percent of total capital costs. The $100,000/yr. was incorporated into the demand charge calculation to facilitate programming. The values are calculated as follows:

- the $/MMBtu/hr was calculated:
  $1,144.00/MMBtu/hr for the 10 MMBtu/hr system
  $716.67/MMBtu/hr for the 60 MMBtu/hr system

- these were scaled linearly to the 100 MMBtu/hr size range.

For the smaller size, a 2 MMBtu/hr turbine was assumed fed by a 50 MMBtu/hr boiler. The turbine cost $160,700, the boiler modifications $130,000. The scale down factor was calculated to be .25

2. Building Block-B1.15 Demand Charges

Monogahela's rates were used and the distribution includes a 60 MMBtu/hr turbine size at a 15 percent frequency as well as a 10 MMBtu/hr. size at a 85 percent frequency. The scale down to .95 is consistent with Monogahela's rate structure at relatively small electricity demands. For the three sizes considered, the demand charges are as follows:

2 MMBtu/hr	(.6MW)	$142,524
10 MMBtu/hr	(2.93 MW)	$154,800
600 MMBtu/hr	(17.5MW)	$738,180

Each of these was scaled to a $/MMBtu/hr and are entered as such. The $100,000/yr for turbine operating costs are included in the values presented in B1.15.

3. Building Block-H8.11, I8.11 Indirect Capital Costs, Construction Indices

These are assumed equal to those attributed to a coal-fired boiler of the 50 MMBtu/hr and 250 MMBtu/hr sizes.

GENERAL DATA

1. Fuel Efficiency - the fuel efficiency equals the product of steam to boiler fuel ratio (.82) and the turbine electricity to steam ratio (.7). The product is .57.

2. Maximum Fraction - the maximum market fraction is determined endogenously by running the steam sector before the machine drive sector and having ISTUM calculate the maximum amount

of electricity that could be produced given AFB's penetration in the steam sector. This value limits the penetration of AFB topping in the machine drive sector.

3. Applicable Industries - The seven industries were selected by virtue of their relatively large steam and electricity demands.

b. Technology Name: LBG Topping Cogeneration
Technology I.D.: 1.25

BUILDING BLOCK DATA

1. Building Block-A1.25 Equipment Costs

The turbine costs are the same as for A1.15. The incremental boiler costs, turbine costs, and totals are as follows:

	Size		
	20 MMBtu/hr		100 MMBtu/hr
Turbine Size	2 MMBtu/hr	10 MMBtu/hr	60 MMBtu/hr
Incremental Boiler Costs	$140,000	$480,000	$2,070,000
Turbine Costs	$160,700	$714,300	$2,266,875
	$300,700	$1,194,300	$4,333,353

Converting these totals to $/MMBtu/hr of turbine capacity and then multiplying by 100 yields the values in A1.25 and a scale down factor of .22.

2. Building Blocks-B1.15, H8.11, I8.11 Turbine Indirect Capital, Construction Costs

See Technology 1.15 for discussion of these blocks.

GENERAL DATA

1. Fuel Efficiency - the ratio of boiler steam to fuel is .72 and the ratio of turbine electricity to steam is .7. The product is .50.

2. Maximum Fraction - See Tech I.D. 1.15

3. Applicable Industries - See Tech I.D. 1.15

c. Technology Name: Coal Topping Cogeneration
Technology I.D.: 5.45

The costs are equal to those of Technology 1.15. Penetration will vary depending on endogenously-determined maximum market fractions.

d. Technology Name: Oil Topp Cogeneration
Technology I.D.: 5.55

These costs are equal to those of Technology 1.25. Penetration will vary depending on the endogenously-determined maximum market fraction.

e. Technology Name: Gas Topp Cogeneration
Technology I.D.: 5.65

Costs equal to those of Technology 1.25. Penetration will vary depending on the endogenously determined maximum market fraction.

GENERAL DATA

GENERAL DATA FOR 5.45, 5.55, 5.65

Fuel Efficiency - See Technology 1.15.

Maximum Market Fraction - See Technology 1.15.

Applicable Industries - See Technology 1.15.

2. Non-Conserving Self-Generation

a. Technology Name: AFB Self Generation
Technology I.D.: 1.35

BUILDING BLOCK DATA

1. Building Block A8.11, C8.11, D8.11, E8.11, H8.11, I8.11 Boiler Support Costs

When self-generating, the turbine is sized at 40 percent the capacity as that of the boiler (given the need to condense the steam exhausted from the turbine). For electricity demands of 20 MMBtu/hr and 100 MMBtu/hr, boilers are sized at 50 MMBtu/hr and 250 MMBtu/hr. Thus, "blocks" from Technology 1.11 should be consulted for explanations of these blocks.

2. Building Block B1.11 Boiler Costs

The block coefficient is increased by 5 percent from that of an AFB boiler supplying process steam since the enthalpy (Btu/lb) is increased. More substantial tubing is required in this case.

3. Building Block C5.71 Demand Charges

The demand charge was outlined for Technology 5.41 (in Steam) and was entered into ISTUM in $/MMBtu/hr of steam demand. To convert to machine drive demand (assumed 40 percent of steam demand), the rate is multiplied by 2.5.

4. Building Block B8.15 Turbine Costs

Turbine costs were derived from General Electric's Handbook of Industrial Steam Turbines and are listed below:

Turbine Costs

Size

	20 MMBtu/hr	100 MMBtu/hr
Turbine Capacity (MW)	5.9	29.3
Turbine Costs	$1,936,725	$5,533,500

O&M costs are assumed 5 percent of turbine costs.

GENERAL DATA

1. Fuel Efficiency - See Technology 1.16

2. Maximum Fraction - See Technology 1.16

3. Service Sector - This technology was considered a potential electricity supplier to the machine drive sector as well as to the electrolytic sector.

4. Applicable Industries - these are all the industries in which machine drive demands exist.

b. Technology Name: LBG Self Generation
Technology ID: 1.45

BUILDING BLOCK DATA

1. Building Block-A8.11, C8.11, D8.11, E8.11, H8.11, I8.11 Boiler Support Costs

See explanation for these blocks from Technology 1.35.

2. Building Block-B1.21 Boiler Costs

For added costs for the increase in enthalpy, the block coefficient from Technology 1.21 was multiplied by 1.05 to account for more substantial tubing.

3. Building Block-C5.71 Demand Charges

See Technology ID 1.35 for discussion of this block

4. Building Block-B8.15 Turbine Costs

See Technology I.D. 1.35 for discussion of this block.

GENERAL DATA

Fuel Efficiency - See Technology 1.26.

Maximum Fraction - See Technology 1.16

Applicable Industries - See Technology 1.35.

c. Technology Name: Coal Self Generation
Technology I.D.: 8.15

This technology has all the boiler support costs of a conventional coal-fired boiler (8.11) and a 5 percent higher cost for the boiler equipment (Block I.D.#: B8.11) to allow for the increased enthalpy (more substantial tubing). The demand charges (C5.71) and turbine costs (B8.15) were described for Technology 1.35.

d. Technology Name: Oil Self Generation
Technology I.D.: 8.25

The technology has all the boiler support costs of a conventional oil-fired boiler (8.21) and a 5 percent higher cost for the boiler equipment (B8.11) to allow for the increased enthalpy (more substantial tubing). The demand charge (C5.71) and turbine costs (B8.15) were described for Technology 1.35.

e. Technology Name: Gas Self Generation
Technology I.D.: 8.35

This technology has all the boiler support costs of a conventional gas-fired boiler (8.31) and a 5 percent higher cost for the boiler equipment (B8.11) to allow for the increased enthalpy (more substantial tubing). The demand charge (C5.71) and turbine costs (B8.15) were described for Technology 1.35.

GENERAL DATA FOR 8.51, 8.25, 8.35

See Technology 1.15 for all components except maximum fractions which are .7 for coal technologies and 1.0 for non-coal technologies (environmental constraints).

3. Energy-Conserving Self-Generation

a. Technology Name: Diesel Engine - Organic Rankine Cycle System (ORCS)

Technology ID: 2.15

BUILDING BLOCK DATA

1. Building Block-A2.15 Equipment Costs

The diesel engine/organic rankine bottoming cycle system (ORCS) has the following characteristics: the engine costs $300/kW[1/], the ORCS $400/kW[2/]; the engine has a heat rate of 8500, the ORCS an efficiency of 22 percent; the engine produces 75 percent of all electricity produced; the system costs $325/kW combined. At 100 MMBtu/hr, the system costs $9,525,200 and is scaled proportionately to 20 MMBtu/hr. O&M costs are 5 percent of capital costs for both technologies.

2. Building Block-C5.71 Demand Charges

See discussion of C5.71 for Technology I.D. 1.35

3. Building Block-H8.11, I8.11 Indirect Capital Costs, Construction Costs

These are assumed equal to that of an oil-fired boiler.

GENERAL DATA

1. Year Available - the leading ORCS manufacture foresees mass production in late 1979.

2. Fuel Efficiency - For each 8500 Btu's of oil fed to the engine, 3412 Btu's of electricity are produced. The remainder is fed as waste heat to the ORCS which converts 22 percent (1119 Btu's) of the waste heat to electricity. The overall electricity to fuel ratio is .53.

1/ Thermo-Electron Corporation, Waltham, Mass.

2/ Sundstrand Energy Systems, Rockford, Illinois.

c. Service Sector - This technology produces electricity and thus could supply either the machine drive or electrolytic sectors.

d. Applicable Industries - these industries possess machine drive demands according to ISTUM's data base.

b. Technology Name: Gas Turbine - ORCS
Technology I.D.: 2.25

BUILDING BLOCK DATA

1. Building Block-A2.25 Equipment Costs

The gas turbine/organic rankine bottoming cycle system (ORCS) has the following characteristics: the turbine costs $200/kW, the ORCS $400/kW; the turbine has a heat rate of 11,000 Btu/kWh, the ORCS an efficiency of 22 percent; the turbine produces 67 percent of the electricity, the ORCS 33 percent; the system costs $266.3/kW combined at 100 MMBtu/hr, the system costs $7,804,800 and the costs are scaled down proportionately to 20 MMBtu/hr.

2. Building Blcok-C5.71 Demand Charges

See discussion of C5.51 for Technology I.D. 1.35.

3. Building Block-H8.11, I8.11 Indirect Capital Costs, Construction Costs

These costs are assumed the same as for an oil-fired boiler.

GENERAL DATA

1. Year Available - See Technology 2.15.

2. Fuels Used - Gas turbines can use either gas or oil - due to the unreliability of gas supply, oil was assumed the preferred fuel.

3. Fuel Efficiency - If 11,000 Btu's are fed into the gas turbine, 3412 Btu's of electricity are produced and 7588 Btu's of waste heat are exhausted. The ORCS will convert 22

percent of this waste heat to electricity, effecting an overall 46 percent efficiency of fuel to electricity.

4. Service Sector - See Technology 2.25.

5. Applicable Industries - See Technology 2.25.

4. Purchased Electricity

a. Technology Name: Conventional Electricity
Technology I.D.: 8.75

BUILDING BLOCK DATA

1. Building Block-A8.75 Equipment Costs

Purchased electricity requires switchgear, transformers and other equipment which approximate $100,000 to $200,00 for a 100 MMBtu/hr demand. The costs scale down proportionately to the 20 MMBtu/hr size demand.

2. Building Block-H8.11, I8.11 Indirect Capital Costs, Construction Costs

Indirect capital costs and construction costs are the same as for all other technologies.

GENERAL DATA

Technology 8.75 competes in the machine drive sector. (Technology 8.76 competes in the electrolytic service sector.)

D. Electrolytic Service Sector

1. Non-Conserving Self-Generation

a. Boiler Costs for Technologies 1.16, 1.26, 8.16, 8.26, 8.36

The boiler is sized at 1500 MMBtu/hr. to provide enough steam to generate 600 MMBtu/hr (175 mW) of electricity. Boiler costs increase non-linearly until roughly 100 MMBtu/hr and then increase linearly with further capacity increases. Thus the slope of capital costs with capacity increases was determined from 100 MMBtu/hr to 250 MMBtu/hr and then used to estimate boiler equipment costs at 1500 MMBtu/hr.

Example: Technology Name: AFB Self Generation
Technology I.D.: 1.16
Building Block-A8.11

For an AFB boiler, the scaling factors for component A8.11 are 1 and 1.95 for sizes 100 MMBtu/hr. and 250 MMBtu/hr respectively. The slope equals .00633 which is multiplied by 1500, yielding the scaling factor for component A8.11 for a 1500 MMBtu/hr boiler. The same method is used for all boiler components for all boilers self-generating electricity.

b. Turbine Costs (B8.16) for Technologies 1.16, 1.26, 8.16, 8.26, 8.36

The cost of a 600 MMBtu/hr condensing turbine (175mW) was derived from General Electric cost data. The capital cost is $9,372,000 with installation costs raising the total cost to $16,401,000.

c. Demand Charges (C5.71) for Technologies 1.16, 1.26, 8.16, 8.26, 8.36

The demand charge for a 600 MMBtu/hr electricity demand was derived from Monongahela's rate structure (see Tech I.D. 5.41, Block # C5.71) and equals $6,582,816/yr. On a dollar per MMBtu/hr of electricity, this equals 2.4 times the values represented in C5.71 which is presented on a dollar per MMBtu/hr of steam.

GENERAL DATA FOR 1.16, 8.16, 8.26, 8.36

a. Fuel Efficiency - Self generation technologies cannot be expected to have efficiencies exceeding those of utility electricity production. The combination of boiler and turbine efficiencies and the need to condense the steam exhausted from the turbine to pump it back into the boiler effect a .33 electricity to fuel ratio.

b. Maximum Fraction - all coal-using technologies have maximum market fractions of .7 to account for environmental restrictions.

C. Service Sector - these technologies are designed to meet electrolytic demands.

d. Applicable Industries - the ISTUM data base reveals electrolytic demands in the Chemicals (SIC 28), Steel (SIC 331), Aluminum (SIC 3334), and Other Primary metals (SIC 334) Industries.

GENERAL DATA FOR 1.26

a. Fuel Efficiency - the overall system efficiency is a function of the boiler efficiency, turbine efficiency and loss of efficiency due to steam condensation. With a coal boiler, the system is 33 percent efficient, the boiler itself having an 82 percent efficiency. Given an LBG boiler efficiency of 72 percent, the total system efficiency is 29 percent.

b. Maximum Fraction - See Technology 1.16.

c. Applicable Industries - See Technology 1.16.

2. Energy Conserving Self-Generation

a. Technology Name: Diesel Engine - ORCS
Technology I.D.: 2.16

BUILDING BLOCK DATA

1. Building Block A2.15 Equipment Costs

These technologies do not realize economies of scale - thus the scale up from 100 MMBtu/hr to 600 MMBtu/hr is six (6).

2. Building Block C5.71 Demand Charge

See discussion on demand charges for Technology 1.16.

3. Building Block H8.11, I8.11 Indirect Capital Costs, Construction Costs

These costs are equal to those of an oil-fired boiler.

GENERAL DATA

1. Fuel Efficiency - See Technology 2.15

2. Service Sector - This technology can produce electricity to meet electrolytic demands

3. Applicable Industries - These industries are those that according to ISTUM's data base have electrolytic demands.

4. Year Available - See Technology 2.15.

3. Conventional Electricity

a. Technology Name: Conventional Electricity
Technology I.D.: 8.76

BUILDING BLOCK DATA

1. Building Block -A8.75 Equipment Costs

Switchgear, transformers and other equipment costs are assumed proportional to demand. Thus the scale up factor from 100 MMBtu/hr to 600 MMBtu/hr is six (6).

2. Building Blocks H8.11, I8.11 Indirect Capital Costs, Construction Costs

These costs are assumed equal to those of a coal-fired boiler.

GENERAL DATA

a. Technology 8.76 competes in the electrolytic service sector.

GENERAL INFORMATION FOR COGENERATION AND SELF-GENERATION TECHNOLOGIES

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TECH ID	TECHNOLOGY NAME	YEAR AVAIL	FUELS USED		FUEL SHARE (1ST FUEL)	FUEL EFFECIENCY COMB USTN	TRAN SMIS	FINL USE	SIZE RANGE (MMBTU/HR) LO	HI	LOAD RANGE (HRS/YR) LO	HI	MAXIMUM FRACTION INCRE MENTL	RETRO FIT	CONSE RVATN
1.15	AFB TOPPING GEN	1982	1		1.00	1.00	1.00	0.57	¯1	¯1	¯1	¯1	1.00	0.00	1.00
1.16	AFB SELF GEN	1982	1		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.70	0.00	1.00
1.25	LBG TOPPING GEN	1980	1		1.00	0.60	1.00	0.70	¯1	¯1	¯1	¯1	1.00	0.00	1.00
1.35	AFB SELF GEN	1980	1		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.70	0.00	1.00
2.15	DIES ORG RANKIN	1980	2		1.00	1.00	1.00	0.53	¯1	¯1	¯1	¯1	1.00	0.00	1.00
2.16	DIES ORG RANKIN	1980	2		1.00	1.00	1.00	0.53	¯1	¯1	¯1	¯1	1.00	0.00	1.00
2.25	GAS TURB ORB	1980	2		1.00	1.00	1.00	0.46	¯1	¯1	¯1	¯1	1.00	0.00	1.00
5.41	DIES ENG WHB EX	1979	2	4	1.30	1.00	1.00	0.38	¯1	¯1	¯1	¯1	1.00	0.00	1.00
5.45	COAL TOPP COGEN	1972	1		1.00	1.00	1.00	0.57	¯1	¯1	¯1	¯1	1.00	0.00	1.00
5.51	DIES EN WHB NEX	1970	2	4	1.23	1.00	1.00	0.57	0	99	¯1	¯1	1.00	0.00	1.00
5.55	OIL TOPP COGEN	1972	2		1.00	1.00	1.00	0.57	¯1	¯1	¯1	¯1	1.00	0.00	1.00
5.61	GASTURB WHB EX	1979	2	4	1.26	1.00	1.00	0.41	¯1	¯1	¯1	¯1	1.00	0.00	1.00
5.65	GAS TOPP COGEN	1972	3		1.00	1.00	1.00	0.57	¯1	¯1	¯1	¯1	1.00	0.00	1.00
5.71	GASTUR WHB NEX	1972	2	4	1.22	1.00	1.00	0.54	0	99	¯1	¯1	1.00	0.00	1.00
8.15	COAL SELF GEN	1972	1		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.70	0.00	1.00
8.16	COAL SELF GEN	1972	1		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.70	0.00	1.00
8.26	OIL SELF GEN	1972	2		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.35	GAS SELF GEN	1972	3		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.36	GAS SELF GEN	1972	3		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.75	CONV ELECTRICTY	1920	4		1.00	1.00	1.00	1.00	¯1	¯1	¯1	¯1	1.00	0.00	1.00
8.76	CONV ELECTRICTY	1920	4		1.00	1.00	1.00	1.00	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.15	COAL SELF GEN	1920	1		1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.16	COAL SELF GEN	1920	1		1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.25	OIL SELF GEN,	1920	2		1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.26	OIL SELF GEN,	1920	2		1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.35	GAS SELF GEN	1920	3		1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00
9.36	GAS SELF GEN	1920	3		1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	1.00

GENERAL INFORMATION FOR COGENERATION AND SELF-GENERATION TECHNOLOGIES

TECH ID	TECHNOLOGY NAME	SERV SECT	DATA QUALITY MAX FRAC	COST	ENER SAVE	ACCELER	CONST PER (YRS)	PHYS LIFE (YRS)	DOE ACCEL (YRS)	LAST UPDATED
1.15	AFB TOPPING GEN	5	B	B		C	2.0	25	3	MAR 17, 1978 7:10:14 AM
1.16	AFB SELF GEN	6	B	B		C	2.0	25	3	MAR 17, 1978 6:56:43 AM
1.25	LBG TOPPING GEN	5	B	B		C	2.5	25	3	MAR 17, 1978 7:14:12 AM
1.35	AFB SELF GEN	5	B	B		C	2.0	25	3	MAR 17, 1978 7:07:44 AM
2.15	DIES ORG RANKIN	5	B	B		C	1.0	20	2	MAR 17, 1978 7:14:34 AM
2.16	DIES ORG RANKIN	6	B	B		C	1.0	20	2	MAR 17, 1978 6:51:21 AM
2.25	GAS TURB ORB	5	B	B		C	1.0	20	2	MAR 18, 1978 4:39:45 PM
5.41	DIES ENG WHB EX	1	B	B		C	1.0	20	2	MAR 17, 1978 4:06:59 PM
5.45	COAL TOPP COGEN	5	B	B		C	2.0	25	1	MAR 17, 1978 7:02:35 AM
5.51	DIES EN WHB HEX	1	B	B		C	1.0	20	1	APR 7, 1978 11:52:19 AM
5.55	OIL TOPP COGEN	5	B	B		C	2.0	25	1	MAR 17, 1978 7:01:44 AM
5.61	GASTURB WHB EX	1	B	B		C	1.0	20	2	MAR 17, 1978 4:08:13 PM
5.65	GAS TOPP COGEN	5	B	B		C	2.0	25	1	MAR 17, 1978 7:00:21 AM
5.71	GASTUR WHB HEX	1	B	B		C	1.0	20	1	APR 7, 1978 11:52:25 AM
8.15	COAL SELF GEN	5	B	B		B	2.0	25	0	MAR 21, 1978 7:05:41 PM
8.16	COAL SELF GEN	6	B	B		B	2.0	25	0	MAR 21, 1978 7:07:22 PM
8.26	OIL SELF GEN	6	B	B		B	2.0	25	0	MAR 21, 1978 8:28:05 PM
8.35	GAS SELF GEN	5	B	B		B	2.0	25	0	MAR 21, 1978 7:42:43 PM
8.36	GAS SELF GEN	6	B	B		B	2.0	25	0	MAR 21, 1978 7:43:53 PM
8.75	CONV ELECTRICTY	5	B	B		B	0.2	25	0	MAR 21, 1978 7:50:43 PM
8.76	CONV ELECTRICTY	6	B	B		B	0.2	25	0	MAR 21, 1978 7:52:08 PM
9.15	COAL SELF GEN	5	A	A		A	2.0	20	0	MAR 21, 1978 10:47:52 AM
9.16	COAL SELF GEN	6	A	A		A	2.0	20	0	MAR 21, 1978 10:49:35 AM
9.25	OIL SELF GEN.	5	A	A		A	2.0	20	0	MAR 21, 1978 10:58:50 AM
9.26	OIL SELF GEN.	6	A	A		A	2.0	20	0	MAR 21, 1978 10:58:04 AM
9.35	GAS SELF GEN	5	A	A		A	2.0	20	0	MAR 21, 1978 11:04:20 AM
9.36	GAS SELF GEN	6	A	A		A	2.0	20	0	MAR 21, 1978 11:04:44 AM

GENERAL INFORMATION FOR COGENERATION AND SELF-GENERATION TECHNOLOGIES

PAGE 3
APR 7, 1978 6:07:58 PM

TECH ID	TECHNOLOGY NAME	20	21	22	23	24	25	26	27	28	29	30	31	32	331	3334	334	34	35	36	37	38	39	01	02	10	14
		APPLICABLE INDUSTRIES (MODIFIED SIC CODES)																									
1.15	AFB TOPPING GEN	1		1				1		1	1	1			1												
1.16	AFB SELF GEN									1					1	1	1										
1.25	LBG TOPPING GEN	1		1				1		1	1	1			1												
1.35	AFB SELF GEN	1		1	1	1	1	1	1	1	1	1		1				1	1	1	1	1	1	1	1	1	1
2.15	DIES ORG RANKIN	1		1	1	1	1	1	1	1	1	1		1				1	1	1	1	1	1	1	1	1	1
2.16	DIES ORG RANKIN									1					1	1	1										
2.25	GAS TURB ORB	1		1	1	1	1	1	1	1	1	1		1				1	1	1	1	1	1	1	1	1	1
5.41	DIES ENG WHB EX	1		1	1	1	1	1	1	1	1	1			1		1		1	1	1	1	1		1	1	1
5.45	COAL TOPP COGEN	1		1				1		1	1	1			1												
5.51	DIES EN WHB HEX	1		1	1	1	1	1	1	1	1	1			1		1		1	1	1	1	1		1	1	1
5.55	OIL TOPP COGEN	1		1				1		1	1	1			1												
5.61	GASTURB WHB EX	1		1	1	1	1	1	1	1	1	1			1		1		1	1	1	1	1		1	1	1
5.65	GAS TOPP COGEN	1		1				1		1	1	1			1												
5.71	GASTUR WHB HEX	1		1	1	1	1	1	1	1	1	1			1		1		1	1	1	1	1		1	1	1
8.15	COAL SELF GEN	1		1	1	1	1	1	1	1	1		1	1				1	1	1	1	1	1	1	1	1	1
8.16	COAL SELF GEN									1					1	1	1										
8.26	OIL SELF GEN									1					1	1	1										
8.35	GAS SELF GEN	1		1	1	1	1	1	1	1	1	1		1				1	1	1	1	1	1	1	1	1	1
8.36	GAS SELF GEN									1					1	1	1										
8.75	CONV ELECTRICTY	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
8.76	CONV ELECTRICTY									1					1	1	1										
9.15	COAL SELF GEN	1		1	1	1	1	1	1	1	1	1		1				1	1	1	1	1	1	1	1	1	1
9.16	COAL SELF GEN									1					1	1	1										
9.25	OIL SELF GEN,	1		1	1	1	1	1	1	1	1	1		1				1	1	1	1	1	1	1	1	1	1
9.26	OIL SELF GEN,									1					1	1	1										
9.35	GAS SELF GEN	1		1	1	1	1	1	1	1	1	1		1				1	1	1	1	1	1	1	1	1	1
9.36	GAS SELF GEN									1					1	1	1										

COGENERATION SELF-GENERATION TECHNOLOGY SPECIFICATIONS

BUILDING BLOCK COEFFECIENT DATA NOT FOUND FOR 9.15 9.16 9.25 9.26 9.35 9.36

BUILDING BLOCK COEFFICIENTS .
PRINTED APR 7, 1978 6:11:05 PM

TECH ID 1.15
UPDATED MAR 22, 1978 1:25:08 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.15	1.00	0.25	1.00
B 1.15	1.00	0.95	1.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 1.16
UPDATED APR 5, 1978 5:19:2

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.11	0.83	9.50
B 8.11	1.00	8.50
C 8.11	0.83	16.60
D 8.11	0.83	3.80
E 8.11	0.83	10.00
H 8.11	1.00	1.00
I 8.11	1.00	1.00
C 5.71	2.40	1.00
B 8.16	1.00	1.00

TECH ID 1.25
UPDATED MAR 17, 1978 10:47:16 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.25	1.00	0.22	1.00
B 1.15	1.00	0.95	1.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 1.35
UPDATED APR 4, 1978 2:16:16 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.11	0.83	0.51	1.95
B 1.11	1.05	0.64	1.81
C 8.11	0.83	0.73	2.66
D 8.11	0.83	0.20	0.71
E 8.11	0.83	0.60	2.00
B 8.15	1.00	0.35	1.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
C 5.71	2.50	0.23	1.00

COGENERATION SELF-GENERATION TECHNOLOGY SPECIFICATIONS
continued

TECH ID 2.15
UPDATED APR 4, 1978 2:16:16 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.15	1.00	0.20	1.00
C 5.71	2.50	0.23	1.00
H 8.11	0.90	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.16
UPDATED APR 4, 1978 2:16:1

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 2.15	1.00	6.00
C 5.71	2.40	1.00
H 8.11	0.90	1.00
I 8.11	1.00	1.00

TECH ID 2.25
UPDATED APR 4, 1978 2:16:16 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.25	1.00	0.20	1.00
C 5.71	2.50	0.23	1.00
H 8.11	0.90	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 5.41
UPDATED MAR 18, 1978 5:10:56 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 5.71	1.00	0.32	1.00
B 5.41	1.00	0.20	1.00
C 5.71	1.00	0.23	1.00
E 8.11	0.83	0.64	2.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 5.45
UPDATED MAR 17, 1978 10:47:16 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.15	1.00	0.25	1.00
B 1.15	1.00	0.95	1.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

COGENERATION SELF-GENERATION TECHNOLOGY SPECIFICATIONS

continued

TECH ID 5.51
UPDATED MAR. 23, 1978 5:09:59 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 5.71	1.00	0.32	1.00
B 5.51	1.00	0.20	1.00
C 5.71	1.00	0.23	1.00
C 8.11	0.50	0.64	1.80
D 8.11	0.04	0.64	1.98
E 8.11	0.70	0.64	2.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
B 8.11	0.29	0.64	2.30

TECH ID 5.55
UPDATED MAR 23, 1978 4:55:02 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.25	1.00	0.22	1.00
B 1.15	1.00	0.95	1.00
H 8.11	0.90	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 5.61
UPDATED MAR 18, 1978 5:10:56 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 5.71	1.00	0.32	1.00
B 5.61	1.00	0.20	1.00
C 5.71	1.00	0.23	1.00
E 8.11	0.83	0.64	2.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 5.65
UPDATED MAR 23, 1978 4:55:02 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 1.25	1.00	0.22	1.00
B 1.15	1.00	0.95	1.00
H 8.11	0.90	1.00	1.00
I 8.11	1.00	1.00	1.00

COGENERATION SELF-GENERATION TECHNOLOGY SPECIFICATIONS

continued

TECH ID 5.71
UPDATED MAR 23, 1978 5:09:59 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 5.71	1.00	0.32	1.00
B 5.71	1.00	0.20	1.00
C 5.71	1.00	0.23	1.00
C 8.11	0.50	0.64	1.80
D 8.11	0.04	0.64	1.98
E 8.11	0.70	0.64	2.00
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
B 8.11	0.29	0.64	2.30

TECH ID 8.15
UPDATED APR 4, 1978 2:16:16 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.11	2.08	0.26	1.00
B 8.11	0.87	0.56	1.86
C 8.11	0.83	0.56	2.05
D 8.11	0.83	0.56	1.91
E 8.11	0.83	0.56	1.85
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
C 5.71	2.50	0.23	1.00
B 8.15	1.00	0.35	1.00

TECH ID 8.16
UPDATED APR 5, 1978 5:11:5

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.11	0.83	11.70
B 8.11	0.83	9.03
C 8.11	0.83	10.50
D 8.11	0.83	9.10
E 8.11	0.83	8.50
H 8.11	1.00	1.00
I 8.11	1.00	1.00
C 5.71	2.40	1.00
B 8.16	1.00	1.00

COGENERATION SELF-GENERATION TECHNOLOGY SPECIFICATIONS continued

TECH ID 8.26
UPDATED APR 5, 1978 5:11:5

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.11	0.48	10.80
B 8.11	0.29	3.15
C 8.11	0.50	8.00
D 8.11	0.04	9.80
E 8.11	0.70	10.00
B 8.16	1.00	1.00
H 8.11	0.90	1.00
I 8.11	1.00	1.00
C 5.71	2.40	1.00

TECH ID 8.35
UPDATED APR 4, 1978 2:16:16 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.11	0.46	0.64	2.10
B 8.11	0.30	0.64	2.30
E 8.11	0.60	0.64	2.25
H 8.11	0.90	1.00	1.00
I 8.11	1.00	1.00	1.00
C 5.71	2.50	0.23	1.00
B 8.15	1.00	0.35	1.00

TECH ID 8.36
UPDATED APR 5, 1978 5:04:4

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.11	0.46	11.00
B 8.11	0.29	13.70
E 8.11	0.70	12.50
B 8.16	1.00	1.00
H 8.11	0.90	1.00
I 8.11	1.00	1.00
C 5.71	2.40	1.00

TECH ID 8.75
UPDATED MAR 23, 1978 4:55:02 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 8.75	1.00	0.20	1.00
I 8.11	1.00	1.00	1.00

COGENERATION SELF-GENERATION TECHNOLOGY SPECIFICATIONS

continued

TECH ID 8.76
UPDATED MAR 23, 1978 4:50:

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 8.75	1.00	6.00
I 8.11	1.00	1.00

BUILDING BLOCKS
PRINTED APR 7, 1978 6:16:05 PM

ID: A 1.15
NAME: CAP EQUIP
LAST UPDATED MAR 31, 1978 5:41:10 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.01
FREQUENCY AND COST DATA:

0.150	7,166.700
0.850	11,440.000
0.000	0.000
0.000	0.000

ID: A 1.25
NAME: CAP EQUIP
LAST UPDATED MAR 31, 1978 5:41:40 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.01
FREQUENCY AND COST DATA:

0.150	7,236.700
0.850	11,940.000
0.000	0.000
0.000	0.000

ID: A 2.15
NAME: CAPITAL EQUIPMENT
LAST UPDATED MAR 17, 1978 7:46:13 AM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

1.000	9,525.200
0.000	0.000
0.000	0.000
0.000	0.000

ID: A 2.25
NAME: CAPITAL EQUIPMENT
LAST UPDATED MAR 17, 1978 7:45:33 AM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

1.000	7,804.800
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0.000	0.000
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COGENERATION AND SELF-GENERATION BUILDING BLOCKS
continued

ID: A 5.71
NAME: SITE PREPARATION
LAST UPDATED MAR 13, 1978 2:34:24 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE S
FRACTION OF COSTS FOR O+M: 0.03
FREQUENCY AND COST DATA:

0.400	605.000
0.400	653.000
0.200	773.000
0.000	0.000

ID: A 8.11
NAME: SITE PREP
LAST UPDATED MAR 12, 1978 6:30:33 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.03
FREQUENCY AND COST DATA:

0.500	541.000
0.400	823.000
0.100	1,761.000
0.000	0.000

ID: A 8.75
NAME: CAPITAL COST
LAST UPDATED MAR 19, 1978 5:27:06 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.500	100.000
0.500	200.000
0.000	0.000
0.000	0.000

ID: B 1.11
NAME: ATMOSPHERIC FLUID BED BOILER
LAST UPDATED MAR 12, 1978 6:38:46 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.12
FREQUENCY AND COST DATA:

0.300	2,800.000
0.500	3,100.000
0.200	3,900.000
0.000	0.000

COGENERATION AND SELF-GENERATION BUILDING BLOCKS

continued

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ID:    B 1.15
NAME:   DEMAND CHARGE
LAST UPDATED APR 7, 1978  3:53:23 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR):  100
TYPE L
FRACTION OF COSTS FOR O+M:  0
FREQUENCY AND COST DATA:
  0.150           8.540
  0.850          17.640
  0.000           0.000
  0.000           0.000
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ID:    B 5.41
NAME:   EQUIPM,ENT
LAST UPDATED MAR 13, 1978  2:38:43 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR):  250
TYPE S
FRACTION OF COSTS FOR O+M:  0.06
FREQUENCY AND COST DATA:
  1.000      25,028.200
  0.000           0.000
  0.000           0.000
  0.000           0.000
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ID:    B 5.51
NAME:   EQUI+PMENT
LAST UPDATED MAR 20, 1978  10:23:03 AM
SIZE OF UNIT COSTED OUT (MMBTU/HR):  250
TYPE S
FRACTION OF COSTS FOR O+M:  0.05
FREQUENCY AND COST DATA:
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  0.000           0.000
  0.000           0.000
  0.000           0.000
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ID:    B 5.61
NAME:   EQUIPM,ENT
LAST UPDATED MAR 13, 1978  2:43:30 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR):  250
TYPE S
FRACTION OF COSTS FOR O+M:  0.06
FREQUENCY AND COST DATA:
  1.000      13,340.200
  0.000           0.000
  0.000           0.000
  0.000           0.000
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COGENERATION AND SELF-GENERATION BUILDING BLOCKS continued

ID: B 5.71
NAME: EQUIPMENT
LAST UPDATED APR 4, 1978 2:04:55 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

1.000	6,695.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: B 8.11
NAME: BOILER EQUIPMENT (GENERAL)
LAST UPDATED MAR 12, 1978 6:54:53 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.115
FREQUENCY AND COST DATA:

0.350	1,500.000
0.550	2,100.000
0.100	2,520.000
0.000	0.000

ID: B 8.15
NAME: EQUIPMENT TURBINE
LAST UPDATED MAR 22, 1978 1:25:55 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

1.000	5,533.500
0.000	0.000
0.000	0.000
0.000	0.000

ID: B 8.16
NAME: EQUIPMENT TURBINE
LAST UPDATED MAR 24, 1978 1:45:22 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 600
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

1.000	16,401.000
0.000	0.000
0.000	0.000
0.000	0.000

COGENERATION AND SELF-GENERATION BUILDING BLOCKS

continued

ID: C 5.71
NAME: DEMAND CHARGE
LAST UPDATED APR 7, 1978 3:53:57 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE L
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.030	1.500
0.940	3.580
0.030	5.670
0.000	0.000

ID: C 8.11
NAME: FUEL HANDLING
LAST UPDATED MAR 13, 1978 3:43:03 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.12
FREQUENCY AND COST DATA:

1.000	467.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: D 8.11
NAME: ENVIRONMENTAL CONTROL SYSTEM
LAST UPDATED MAR 12, 1978 6:57:38 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

1.000	2,340.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: E 8.11
NAME: FEEDWATER SYSTEM AND UTILITIES
LAST UPDATED MAR 12, 1978 7:01:07 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.07
FREQUENCY AND COST DATA:

0.200	210.000
0.500	260.000
0.300	660.000
0.000	0.000

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ID:    H 8.11
NAME:  INDIRECT CAPITAL COSTS (ENGIN, CONTIN)
LAST UPDATED MAR 12, 1978  7:08:23 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR):  0
TYPE M
FRACTION OF COSTS FOR O+M:  0
FREQUENCY AND COST DATA:
  0.550          1.300
  0.350          1.400
  0.100          1.500
  0.000          1.650


ID:    I 8.11
NAME:  CONSTRUCTION INDICES
LAST UPDATED MAR 12, 1978  7:09:36 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR):  0
TYPE M
FRACTION OF COSTS FOR O+M:  0
FREQUENCY AND COST DATA:
  0.400          0.870
  0.400          0.970
  0.200          1.070
  0.000          1.250


PROGRAM EXITED
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CHAPTER V

SOLAR AND GEOTHERMAL TECHNOLOGIES

This chapter presents the cost structure of the solar and geothermal technologies that compete in the ISTUM model. The general integration of solar and geothermal technologies into the ISTUM logic is discussed in Volume I, Chapter II.

Two solar steam technologies and one geothermal technology compete in the steam service sector. The two solar technologies have the same capital cost structure only each is appliable in a different load factor range.[1/] The difference is in the fuel share division between solar energy and the fossil fuel backup. At high load factors the fossil backup equipment will be operated more frequently. This results in a higher fuel share for the fossil fuel at high load factors. In the space heat service sector where the specified load factors are lower, only one solar technology was required.

A. Solar Steam Technologies 3.11 and 3.21

The solar steam system modeled in ISTUM had the following characteristics:

1. The system was located in the best insolated area of the United States, as determined by the Intertechnology Corporation in its study entitled Analysis of the Economic Potential of Solar Thermal Energy to Provide Industrial Process Heat. Regional insolation variability is captured by a

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1/ See the yellow solar sheet under column headed load range.

multiplier which reflects the increase in cost of a system due to a decrease in regional insolation. (Component G3.11)

2. It's size was specified to be a 50 MMBtu/hr system, supplying 300^{O}F steam to a plant operating 4000 hours a year.

3. The collectors used for the system are single axis tracking, parabolic trough collectors.

4. Collector efficiency was taken directly from ITC data, with collectors supplying 837,000 Btu/f^{2}/year.

5. Backup, in the form of a conventional, oil fired steam supply system, was assumed to be necessary. Costs used for this system were those generated for oil fired conventional systems modeled in ISTUM with one exception; it was assumed scrubbers would never be necessary. Backup is used 25 percent of the time for 4000 hour system, and, 57 percent of the time for a 7000 hour system.

6. Feedwater and utility costs were those used for similar sized ISTUM technologies.

7. Site prep and land costs. Each half acre of collector area requires one acre of cleared and graded land that is surrounded by fencing.

8. Storage was determined to be unnecessary due to the presence of fossil backup. Only that amount of storage necessary for the few minutes it would take to start up the fossil system was included in the cost distribution.

9. The system is technically capable of supplying steam at temperatures up to 600^{O}F. Feed water temperature is 60^{O}F.

The components used to represent these different factors are listed below. These components all reflect the specifications and costs of the system described above.

BUILDING BLOCK DESCRIPTIONS

a. Building Block-A3.11 Collectors

This cost of $4,062,000 is based on

- collector cost per square foot
- insolation and collector efficiency
- plant size and load factor.

Concentrating collectors are assumed to be $17.00 a square foot, delivered, not installed. This is a cost that was arrived at by two completely separate methods. First, a weighted average was taken of all concentrating collector costs, as quoted by different studies (including the above mentioned ITC study and the MITRE SPURR/METREK model). Second, vendors were contacted for cost information. ACUREX - AEROTHERM quoted $17.00 a square foot delivered, and this figure was accepted, for their collector best approximated the technical specifications of the ITC and ISTUM collectors modeled.

Insolation and collector efficiency were taken directly from the ITC study. This study supplied data that had to be normalized in two ways, in order to meet the specifications of the ISTUM system.

1) ITC's data was for a system that supplied steam only up to 500°F. While the ISTUM system generates steam up to 600°F, collector efficiency decreases as temperature requirements increase. The decrease in efficiency from 500°F

to $600^{o}F$ was determined by estimating the average percentage decrease of 200^{o}-300^{o}, 300^{o}-400^{o}, and 400^{o}-500^{o} and applying this average to the 500^{o}-600^{o} range with the following result:

	200^{o}	300^{o}	400^{o}	500^{o}	600^{o}
$kBtu/f^2/yr.$ (Region VI)	630	620	552	500	460

2) ITC established 6 insolation regions, based on data from 90 cities. To establish what the best theoretical insolation could be, variability between cities in Region VI had to be measured. The highest possible insolation for region VI was 35 percent greater than the regional average, or 837,000 $Btu/f^2/yr$. The load factor was multiplied by the plant size in order to arrive at the amount of Btus needed by the plant in a given year.

50 MMBtu/hr. x 4000 hrs. = 2×10^{11} Btus a yr. This was then divided by collector output, in order to determine the amount of collector footage required.

$$\frac{2 \times 10^{11} \text{ Btus unit}}{837{,}000 \text{ Btus/ft}^2\text{/yr}} = 238{,}949 \text{ sq. ft. of collectors}$$

This amount of collector footage is then multiplied by $17.00 to arrive at total collector cost.

238,949 sq. ft. x $17.00/sq. ft. = $4,062,126

b. Building Block-B3.11 Site Preparation

It is assumed that each square foot of collector area requires 1.5 square feet of land. The square footage, 238,947, was multiplied by 1.5 in order to determine the amount of acreage needed.

238,947 x 1.5 = 358,423

358,423 ÷ 43,560 (sq. ft. in an acre) = 8.22 acres

These nine acres were assumed to cost 5,000 dollars an acre, for a base cost of 45,000 dollars. Clearing costs of \$1.63, \$1.97, and \$2.27 a square yard were used.

9 (acres) x 4840 (sq. yds. per acre) = 43,560 sq. yds.

\$1.63 x 43,560 = \$71,000 + 45,000 = \$126,000 dollars
\$1.97 x 43,560 = \$85,813 + 45,000 = \$131,000 dollars
\$2.27 x 43,560 = \$98,881 + 45,000 = \$144,000 dollars

Fencing costs are assumed to be 3.41 a linear yard. Assuming a square collector field, 835 yards of fencing are necessary.

9 acres x 4840 (sq. yds.) = 43,560

$\sqrt{43,560}$ = 208 linear yds.

208.7 linear yds. x 4 sides to a square = 834 linear yds.
834 x \$3.41 = \$2846.80

Final site prep costs are:

best:	71,000 + 45,000 + 3,000 = \$129,000 dollars
	86,000 + 45,000 + 3,000 = \$134,000 dollars
worst:	99,000 + 45,000 + 3,000 = \$147,000 dollars

These site prep costs were obtained from Process Plant Estimating, Evaluation and Control by Kenneth Gutherie. The figures were inflated from 1971 to 1977 using the WPI.

c. Building Block-3.11 Installation Costs

Installation costs are the single most expensive component of a solar system. Information was obtained from several vendors, ACUREX-AEROTHERM, SUNPOWER SYSTEMS, and OWENS ILLINOIS. All quoted suprisingly high costs, ranging from $23.00 to $83.00 a square foot. Originally, costs were developed for four unit prices.

unit price	$23.00/ft^2	$43.00/ft^2	$63.00/ft^2	$83.00/ft^2
total cost	$5,496,000	$10,275,000	$15,054,000	$19,833,000

Programming requirements reduced this to the three cases found in this building block. It should be stressed that these high ranges were verified by several vendors, and it is these installation costs that most differentiate ISTUM's cost distributions from those of other studies.

d. Building Block-3.11 Fossil Back Up

As was stated before the point estimate used for this figure is based on the costs used for ISTUM's conventional oil fired steam system, which is discussed in the Fossil Energy Section of this appendix.

e. Building Block-3.11 Feedwater and Utilities

These costs are also taken directly from the feedwater and utilities costs for similar sized ISTUM technologies which are discussed in the conventional technology section of this report.

f. Building Block-3.11 Temperature

The temperature multiplier was used to inflate system costs, for collector efficiency decreases as temperature requirement increase. The data used was the ITC data cited previously. The decrease in efficiency was measured as a percentage, and these percentages became the different cases that occur in the temperature building block.

Temperature	300^{o}		400^{o}		500^{o}		600^{o}
$Btu/ft^2/yr$	620		552		500		400
Efficiency decrease		12 percent		24 percent		35 percent	
Temp. mult.	1.0		1.12		1.24		1.35

g. Building Block-3.11 Insolation Multiplier

The insolation multiplier is based on ITC regional insolation data. The average efficiencies, expressed as $KBtu/f^2/yr$ for a 300^{o} system are listed below.

	$KBtu/f^2/yr$	Multiplier
I	192	4.36
II	290	2.89
III	356	2.35
IV	384	2.18
V	436	1.92
VI	620	1.35
Region VI High range	837	1.0

The multiplier represents what multiple of the original collector area is needed to supply 50 MMBtu/hr., $300^{o}F$ steam for a plant with a 4000 hour load factor. These regions were combined in order to establish the cases used in the building block. Region I was dropped completely for the data supplied by ITC indicated a solar system located in that region could not realistically supply steam at temperatures greater than 400^{o}F.

Non-Cost Related Information

Year Available/DOE Acceleration

While solar concentrating systems are presently available and actively being marketed by several companies, industry generally perceives them to be in a prototype stage of development. This leads to the conclusion that they will not be fully commercially accepted until at least 1980. It is also safe to assume DOE has had a positive role in their acceptance, due to several DOE funded demonstration projects and studies, such as the ITC report.

Fuel Efficiencies

Fuel efficiencies were calculated assuming 82 percent boiler efficiency of the oil back up system and using a 3000/1000 and 3000/4000 solar/oil energy ratio.

Size Range

While ISTUM does not model a size greater than 250 MMBtu/hr., it is necessary to illustrate solar's technical limitations by emphasizing a certain constant as an upward bound (200 MMBtu/hr), rather than use a minus one, which indicates no size limitations. Solar systems are at present, quite small, and show little technical promise for large scale industrial applications, even at sizes such as 50 or 100 MMBtu/hr. It would be fallacious to present solar as a technology that can be adapted to applications that would require, at best, 45 acres of collectors and at worst, close to 200 acres of collectors.

Maximum Market Fraction

The thirty percent figure used is based on several assumptions incorporating technical and application-related limitations to solar's commercial viability. The two major constraints are temperature and land availability.

1. Temperature

The temperature requirements of industry are the major factor in determining the technical applicability of solar technology. The maximum market fraction is limited by solar's ability (or inability) to meet industry temperature requirements. The original MOPPS model set the highest attainable temperatures for solar systems at 650^{o}F (350^{o}C), and this was lowered to 600^{o}F in ISTUM. This makes the initial maximum market fraction large, (e.g., 60 percent for direct steam). Batelle Columbus Laboratories in a study entitled <u>Survey of the Applications of Solar Thermal Energy Systems to Industrial Process Heat</u> concluded that a large amount, 82 percent, of all steam is used at temperatures less than 550^{o}F. Solar concentrating collectors can generate temperature up to 600^{o}F. This expands the market available to solar technologies, but limits the use of BCL data to determine the exact size of the data, for they only specify how much steam is required above 550^{o} rather than 600^{o}F. Comparison with similar studies demonstrates this figure is high and could be as low as 40 or 50 percent. By eliminating certain SICs that use very high temperature steam, an overall sixty percent figure appears reasonable.

BCL concluded that a considerable (but, as of yet, unquantified) amount of process heat is used at temperatures greater than the actual manufacturing process requires. This leads to the possibility that the maximum market share for solar would be greater if estimated by manufacturing process requirements rather than actual application requirements. The data needed is extremely site and process specific.

2. Land Availability

Land constraints cut this sixty percent maximum market fraction in half. ISTUM technologies rarely have to worry about microgeography, and data on land availability as well as plant location are limited. It is safe to assume, however, that at least half of all facilities are located in or near urban areas. Given the large requirement of solar systems, even in a well insolated area, facility siting in urban areas is impossible. This reduces the sixty percent fraction to the thirty percent value used in the model.

Applicable SICs

Solar was not included in several SICs (28, 29, 32, 331, 3334, 334, 34). The reason for this is simple; the use of steam by these industries is at extremely high temperatures, considerably above solar's technical limits. The ITC study documents this fact in some detail.

Construction and Physical Life

The data used for these categories came from the ITC and MITRE studies as well as vendors, and there was little discrepancies if any between these different sources.

B. Solar Space Heat Technology-3.112

1. The system was located in the best insolated area of the United States, as determined by the Intertechnology Corporation in its study entitled Analysis of the Economic Potential of Solar Thermal Energy to Provide Industrial Process Heat. A multiplier was used (component G 3.11) in order to incorporate into the costs variability in regional insolation.

2. It's size was specified to be a 10 MMBtu/hr system, supplying space heat in the form of low temperature steam, (212^{o}F) to a plant operating 2500 hours a year.

3. The collectors used for the system are single glazed, flat plate collectors.

4. Collector efficiency was taken directly from ITC data, with collectors supplying 609,000 Btu/f^2/year.

5. Backup was not included in the system.

6. Feedwater and utility costs were not modeled, for the space heat system is a closed system that needs a minimal amount of water.

7. Site Prep and land costs were not treated as a separate component; these costs were folded into a general installation cost.

8. Roughly two days of storage was folded into the cost distribution of the base or ideal system. This increases as insolation decreases and larger amounts of stored energy are necessary.

9. Feedwater temperature is 60^{o}F.

BUILDING BLOCK DESCRIPTIONS

The components used to represent these different factors are listed below. These building blocks all reflect the specifications and costs of the system described above.

a. Building Block-A3.112-Collectors

This cost of $493,000 is based on

- collector cost per square foot
- insolation and collector efficiency
- plant size and load factor.

Single glazed flat plate collectors are assumed to be $12.00 a square foot, delivered, not installed. This cost was arrived at by surveying vendors and establishing a weighted average of collector prices quoted in different research studies (including the above mentioned ITC study, the MITRE SPURR/METREK model, and an OTA study). Twelve dollars a square foot appeared to be the price most representative of the different flat plate collectors currently available.

Insolation and collector efficiency was taken directly from the ITC study. The data in this study was generated for a 200°F system; it was assumed there would be no noticeable drop in efficiency between 200° and 212°, the temperature requirement of the ISTUM system. The data was normalized to develop the highest possible amount of insolation.

ITC established 6 insolation regions, based on data from 90 cities. To establish what the best theoretical insolation could be, variability between cities in Region VI had to be measured. The highest possible insolation for region VI was 35 percent greater than the regional average, or 609,000 Btu/f^2/yr. The load factor was multiplied by the plant size in order to arrive at the amount of Btus needed by the plant in a given year.

10 MMBtu/hr. x 2500 hrs. = 2.5 x 10^{10} Btus a year. This was then divided by collector output, in order to determine the amount of collector footage required.

$$\frac{2.5 \times 10^{10}}{609{,}000 \text{ Btus/ft}^2\text{/yr.}} = 41{,}051 \text{ sq. ft. of collectors}$$

This amount of collector footage was then multiplied by $12.00 to arrive at a total collector cost.

41,051 sq. ft. x $12.00 sq. ft. = $492,611

b. Building Block-3.112 Installation

Installation costs are the single most expensive component of a solar system. Information was obtained from several vendors, ACUREX-AEROTHERM, SUNPOWER SYSTEMS, and OWENS ILLINOIS. All quoted suprisingly high costs, ranging from 10.00 to 50.00 a square foot, depending on the use of the solar thermal energy produced by the flat plate collectors. Research studies quote lower costs for space heating systems. It was decided to use three costs $10.00, $20.00 and $30.00 a square foot to represent the range of costs for installing a space heat system.

unit price	$10.00/f^2	$20.00/f^2	$30.00/ft
	$411,000	$821,000	$1,232,000

c. Building Block-C3.112 Storage

Roughly two days of storage, or 15.5 hours, was modeled into the ideal system. The insolation multiplier expands this into a six day system for the region with the least amount of insolation. The storage system is hot water, with costs estimated by the gallon. A 10 MMBtu/hr space heat system uses slightly less than 8000 gallons of water per hour. Three costs were used to establish the cost frequency distribution: \$.60 a gallon, \$1.10 a gallon, and \$1.50 a gallon. These costs were obtained from a number of research studies, including the ITC report, th MITRE SPURR/METREK model, and an Office of Technology Assessment Report on solar energy.

8000 gallons x \$.60 = 4800 x 15.5 hours = \$74,400 dollars

8000 gallons x \$1.10 = 8800 x 15.5 hours = \$136,000 dollars

8000 gallons x \$1.50 = 12,000 x 15.5 hours = \$186,000 dollars

d. Building Block-G3.11 Insolation Multiplier

This component is documented in the solar steam section.

e. Building Block-H8.11 Indirect Capital Cost Multiplier

This component is documented in the Fossil Energy section.

Non-Cost Related Information

Year Available/DOE Acceleration

Solar flat plate systems have been available for many years, and have become increasingly popular in the post-embargo era. While DOE funds many residential and commercial projects, industrial space heating receive little funding, making it doubtful whether DOE's programs will accelerate industrial use of space heat.

Size Range and Load Factor

It is unlikely that solar flat plate systems will be used for large space heating systems of 25 MMBtu/hr., let alone a 100 MMBtu/hr. system. However, it is technically possible to build a system that large, and 100 MMBtu/hr was specified as the upward bound of space heat applicability. Even though ISTUM does not model a system greater than 100 MMBtu/hr., a negative one was not used for that would give the impression that there is no upward limit to solar's applicability. The load factor was limited to 4000, due to the storage specifications included in the cost distributions.

Maximum Market Fraction

Flat plate systems temperatures require acreage that does not limit its applicability. In the least insolated area of the United States, a solar flat plate system does not require more than five acres of land.

Applicable SICs

Space heat is needed at roughly the same low temperature by all industries. There is no reason to assume why any particular industry would not be technically able to use a solar space heating system.

Construction and Physical Life

The data used for these categories came from the ITC ad MITRE studies as well as vendors, and there was little discrepancies if any between these different sources.

C. Geothermal Steam Technology 4.11

The geothermal steam system modeled in ISTUM had the following characteristics:

1) The system was a geothermal hot water system, extracting and transporting geothermal hot water that is flashed into steam by its end users.

2) It's size was specified to be 2000 MMBtu/hr, supplying high or low temperature steam 4000 or 7000 hours per year.

3) Distribution costs for 20, 100 MMBtu/hr industrial facilities were folded into the cost distributions.

4) Reservoirs with three different energy contents per pound of hot water were folded into the cost distributions. The three energy values are 1200 Btu/lb., 600 Btu/lb., and 200 Btu/lb.

5) The flashing of hot water into steam does not require any temperature raising heat exchangers or other heat boosting equipment.

6) There was a ten percent loss in energy content when the water was flashed into steam.

7) Site preparation costs for drilling, extraction, and transportation are folded into the costs developed for each of these components.

8) Exploration expenses were a constant for the systems costed out; the relative "fertility" or commercial potential of a field was folded into the cost distributions through the use of different drilling success rates when calculating production costs.

9) Environmental control and fluid purification costs are expressed as a percentage of production costs (this is due to data limitations). Elimination of pollutants takes place before the fluid is transported to the end user.

10) Energy content of the geothermal fluid was a function of well depth.

11) The terrain surrounding the reservoir and the pipelines is not a significant factor in the development of the cost distributions.

Basic system and cost specification are listed in Tables V-I and II. Each piece of data is documented and explained. It is this collection of data that was used to develop the building blocks for geothermal steam.

TABLE V-1

SYSTEM SPECIFICATIONS

	High Temp.	Medium Temp.	Low Temp.
Flow (lbs./hr)	500,000	500,000	500,000
Btus/lb.	1,200	600	200
Well Depth (ft.)	7,000	6,000	5,000
Well Life (yrs.)	10	10	10
Number of Wells	4	8	23
Water-Steam Conversion Efficiency	.9	.9	.9
Success Rate (% of wells drilled that produce water)	60%,80%,90%	60%,80%,90%	60%,80%,90%
Average Transportation Distance - well to pipeline (miles)	.5	.5	.75
Reinjection Rate (Ratio of Producing wells to Reinjection wells)	2/1, 4/1, 6/1	2/1, 4/1, 6/1	2/1, 4/1, 6/1

TABLE V-2

COST SPECIFICATIONS

Drilling Cost	1200 Btu/lb.	600 Btu/lb.	300 Btu/lb.
Producing Well ($/ft)	$123.00	$123.00	$123.00
Exploratory Well ($/ft)	$110.00	$110.00	$110.00
Reinjection Well ($/ft)	$ 97.00	$ 97.00	$ 97.00
Environmental Control and Fluid Purification (% of cost of producing well)	25%,30%,35%	20%,25%,30%	20%,25%,30%
Pipe Cost			
$/ft-12" diameter	$ 73.00	$ 73.00	$ 73.00
$/ft-36-48" diameter	$343.00	$343.00	$343.00

BUILDING BLOCK DESCRIPTIONS

a. Building Block-A4.11 Exploration and Discovery

Exploration and discovery expenses were based on data obtained from the Stanford Research Institute's Economic Analyses of Geothermal Energy Development in California, V. 2. These base costs were normalized to meet the specifications of the geothermal system modeled in ISTUM (Table III). The following changes were incorporated into the ISTUM data.

1) The area leased and explored in ISTUM was five times greater than the area in the SRI cost model (37,500 acres vs. 7,500 acres). Well costs related to area such as rent, number of wells drilled, geophysical testing, etc.) was increased linearly. The SRI study analysed geothermal potential in the area of California that had been known for its geothermal activity before actual exploration took place. This type of knowledge cannot be assumed for the ISTUM geothermal system, and the area to be explored was increased by a factor of five in order to make the exploration activity more realistic.

2) Test wells were 7000 feet deep and cost $110 a foot. The original SRI data was for 6000 foot wells which cost $90 a foot to drill. High temperature wells are assumed to be 7000 feet deep by ISTUM, and $110.00 a foot is the assumed cost of a non-producing well when drilling and production expenses are calculated. These figures are documented further on in this appendix.

3) The success rate for test wells was one in 20. The SRI cost model used a success rate

of one in 10. The lower success rate was determined by examining other cost analyses of geothermal projects. The SRI model examined an area of geothermal activity that is quite active, while the ISTUM exploration component is more of an average of real world experience.

4) The data was inflated to 1977 dollars.

5) The ISTUM system required approximately thirty percent of the total energy required by the SRI system. The normalized SRI costs were therefore multiplied by .3 in order to arrive at the final ISTUM costs.

A point estimate was used in this component, rather than a range of cost. It was felt that enough data was not available to construct a range that reflected the real world as accurately as the SRI estimate.

Even though the SRI estimate is in the form of one final, exploration cost, it effectively demonstrates the relative importance of each aspect of exploration and discovery in determining the final cost of the this component.

TABLE V-3

SRI, ISTUM SOLAR COST COMPARISON

ORIGINAL SRI DATA		ISTUM DATA
Activity	Total Cost ($ thousands)	Total Cost ($ thousands)
Pre-lease	854	1,486
Lease bonus	240	372
Geology and geochemistry	1,814	3,156
Rent	240	372
Taxes (ad valorem) 2-½% of lease bonus	6	11
Geology and geophysics, heat flow	1,334	2,321
Rent and ad valorem taxes	123	190
Exploratory drilling	5,400	23,847
3 Step-out wells	1,620	1,431
Ad valorem tax	6	11
Rent	127.5	198
	11,764.5	33,395
Overhead/Management (5%)		x 1.05
		35,065

b. Building Block-B4.11 Drilling and Production

The three point estimates appearing in this building block were distilled from twenty seven, separately calculated cost estimates were originally generated for this component. The initial range included reinjection wells which later were turned into a separate component. The original twenty seven calculations, then become nine. This new set of costs was easier to fit into the program, and allowed the computer to do many calculations previously done by hand.

a) separating possible costs into three categories - 300 Btu/lb. of hot water, 600 Btu/lb. of hot water, and 1200 Btu/lb. of hot water

b) applying a certain drilling success ratio 60 percent, 80 percent, 90 percent for medium and high temperature, 70 percent, 80 percent, 90 percent for low temperature resevoirs applications.

c) calculating how many producing and non-producing wells would be drilled for a reservoir with given heat content.

d) applying different depths for each reservoir -

200 Btu/lb - 5000 ft.
600 Btu/lb - 6000 ft.
1200 Btu/lb.- 7000 ft.

and then calculating drilling costs.

$123 a foot for producing wells
$110 a foot for non-producing wells.

The nine possible cases are arrived at by:

High Temperature

60 percent success ratio
80 percent success ratio
90 percent success ratio

Medium Temperature

60 percent success ratio
80 percent success ratio
90 percent success ratio

Low Temperature

70 percent success ratio
80 percent success ratio
90 percent success ratio

One example is presented below.

Temp: High (1200 Btu/lb)
Flow: 500,000 lbs per hr.
Energy Flow per well: 1200 x 500,000 lb/hr. x .9 (efficiency) = 5.4×10^8 Btu
2,000 MMBtu/hr ÷ 5.4×10^8 Btu = 3.7 wells needed
4 wells x a) 60% success rate = 6.16 = 7 wells
b) 80% success rate = 4.6 = 5 wells
c) 90% success rate = 4.1 = 5 wells

a) 7 wells

4 producing = 7000 ft x $123/ft x 4 (# of wells)= $3,444,000
3 non-producing = 7000 ft x $110/ft. x 3 = $2,310,000 + 3,444,000 = $5,754,000

b) 5 wells

4 producing = 7000 ft x \$123/ft. x 4 =
\$3,444,000

1 non-producing = 7000 x \$110 /ft. x 1 =
\$770,000

\$770,000 + 3,444,000 = 4,214,000

c) same as b

Temp: Medium (600 Btu/lb.)

Flow: 500,000 lbs per hr.

Energy Flow per well: 600 x 500,000 lbs/hr. x .9 (efficiency = 2.7×10^8 Btu

2,000 MMBtu/hr ÷ 2.7×10^8 Btu = 7.4 wells needed

8 wells x a) 60% success rate = 13.3 = 14 wells

b) 80% success rate = 10 = 10 wells

c) 90% success rate = 8.888 = 9 wells

a) 14 wells

8 producing = 6000 ft. x \$123/ft. x 8 (# of wells) =
\$5,904,000

6 non-producing = 6000 ft. x \$110/ft. x 6 =
\$3,960,000

\$5,904,000 + \$3,960,000 = 9,864,000

b) 10 wells

8 producing = 6000 ft. x \$123/ft. x 8 = \$5,904,000

2 non-producing = 6000 ft. x \$110/ft. x 2 = \$1320,000

\$5,904,000 + \$1,320,000 = \$7,224,000

c) 9 wells

8 producing = 6000 ft. x $123/ft. x 8 = $5,904,000

1 non-producing = 6000 ft. x $110/ft. x 1 = $666,000

$660,000 + $14,904,000 = $6,564,000

Temp: Low (200 Btu/lb.)

Flow: 500,000 lbs. per hr.

Energy Flow per Well: 200 x 500,000 lbs/hr. x .9 = $.9 \times 10^8$ Btu

2,000 MMBtu/hr. ÷ $.9 \times 10^8$ Btu = 22.22 wells needed

23 wells x a) 70% success rate = 31.7 = 32 wells

b) 80% success rate = 28.75 = 29 wells

c) 90% success rate = 25.5 = 26 wells

a) 32 wells

23 producing = 5000 ft. x $123/ft. x 23 = $14,145,000

9 non-producing = 5000 ft. x $110/ft. x 9 = $4,850,000

$4,850,000 + $14,145,00 = $18,995,000

b) 29 wells

23 producing = 5000 ft. x $123/ft. x 23 = $14,145,000

6 non-producing = 5000 ft. x $110/ft. x 6 = $3,300,000

$14,145,000 + 3,300,000 = $17,445,000

c) 26 wells

23 producing = 5000 ft. x $123/ft. x 23 = $14,145,000

3 non-producing = 5000 ft. x $110/ft. x 3 = 1,650,000

$1,650,000 + $145,145,000 = $15,795,000

These figures were changed slightly in order to meet programming requirements. The other point estimates were arrived at through the same process.

TABLE V-4

GEOTHERMAL DRILL AND PRODUCTION COSTS

	High temp. Resevoir ($ thousands)	Medium temp. Resevoir ($ thousands)	Low temp. Resevoir ($ thousands)
High Cost	5,754	9,864	18,995
Middle Cost	4,214	7,224	17,445
Low Cost	4,214	6,564	15,295

The costs and well specifications come from several sources.

1) -flow-

- Stanford Research Institute, Economic Analysis of Geothermal Energy Development in California. V. 1, May 1977, pps. 128-133.

- Battelle Pacific Northwest Laboratories, Geothermal Energy Potential for District and Process Heating Applications in the U.S. - An Economic Analysis. August, 1977, p. 14.

2) -Heat Content (Btus/lb.)-

- Stanford Research Institute - op cit., pps 128-133.

- Batelle Pacific Northwest Laboratories, op. cit., pps 14-23.

3) -cost per foot of well drilled-

- Stanford Research Institute, op. cit., pps. 48, 128-133.

- Batelle Pacific Northwest Laboratories, op. cit, pps. 14-23.

4) -drilling success rate-

- Stanford Research Institute, op. cit., V. 2 pps 73-83.

- Lawrence Livermore Laboratories, Present Status and Future Prospects for Nonelectrical Uses of Geothermal Resources, October 15, 1975, pps. 15-18.

5) -well depth-

- Stanford Research Institute, op. cit., pps 128-133.

- Batelle Pacific Northwest Laboratories, op. cit, pps 14-23.

It should be noted that the sources listed above served as guides and general data sources for the assumptions used in the cost calculations. Because of the highly site-specific nature of geothermal resources, the data supplied by these studies was combined and used in a liberal fashion when determining the cost distribution of geothermal steam.

c. Building Block-C4.11 Transportation Costs

The costs found in this building block represent the cost of transporting geothermal fluid from the well to a central pipeline. Each type of reservoir costed out had a different number of wells and hence a different transportation cost. The three figures presented above are these point estimates out of a wide range of possible costs; programming requirements allow for the modeling of only the low cost, high cost, and some point in between.

Costs were calculated by assuming some average distance between the well and central pipeline and also assuming a minimum amount of central pipeline.

a) Low Temperature Reservoir of 200 Btu/lb. of steam has 23 wells. Average distance from the well to the pipeline is .75 miles. Six miles of main pipeline is necessary, roughly one mile for every four wells. The pipeline costs modeled are for low temperature, residential applications.

The fluids transported by these pipelines are not as corrosive as the higher temperature fluids modeled in ISTUM. Therefore, the overall cost of the system is multiplied by 1.1, in order to capture the extra cost per foot of transporting geothermal fluids that are of a higher temperature and corrosive. The ten percent extra cost is an assumption that hopes to capture the extra cost, but is not based on any documented engineering data.

b) Middle Temperature Reservoir of 600 Btu/lb of steam has 8 wells. Average distance from the well to the pipeline is .5 mile. Two miles of pipeline is considered necessary. This temperature was also multiplied by 1.1.

c) High Temperature Reservoir of 1200 Btu/lb. of steam has 4 wells. Average distance from the well to the pipeline is .5 miles. One mile of central pipeline is considered necessary. Again, the base cost is multiplied by a constant in order to reflect the higher cost of high temperature geothermal fluid; the multiplier is 1.2.

Pipeline costs are $74.00 a linear foot for 12 inch diameter pipe, and $363.00 a linear foot for 36-48 inch diameter pipe. Well to main pipelines are 12 inches in diameter; central pipelines are 36-48 inches in diameter. These costs include site prep, clearance, installation, and engineering costs. It is assumed the pipe is being laid in an area that is topographically suitable to the construction of a pipeline.

Three calculations performed are presented below.

High Temperature Resevoir

- 4 wells
- each well .5 miles (2640 feet) from main pipeline, $74.00 a linear foot
- one mile of central pipeline necessary
- base cost multiplied by 1.2 to illustrate extra cost associated with transporting higher temperature geothermal fluids.

4 wells x 2640 feet = 10,560 feet of pipe
10,560 x $74.00/lin. ft. =$781,440
mainpipeline 1 mile (5280 feet) x $363.00/lin.ft. = $1,916,640
$781,440 + $1,916,640 = $2,688,080
$2,688,080 x 1.2 = $3,225,696

Medium Temperature Resevoir

- 8 wells
- each well .5 miles (2640 feet) from main pipeline, $74.00 a linear foot
- one mile of central pipeline necessary
- base cost multiplied by 1.1 to illustrate extra cost associated with transporting higher temperature geothermal fluids.

8 wells x 2640 feet = 21,120 feet of pipe
21,120 x $74.00/lin. ft. = $1,562,880
mainpipeline 2 mile (10,560 feet) x $363.00/lin.ft. = $3,833,280
$1,562,880 + 3,833,280 = $3,479,520
$3,479,520 x 1.1 = 5,935,776

Low Temperature Resevoir

- 23 wells
- each well .75 miles (3960 feet) from main pipeline, $74.00 a linear foot
- 4 miles of central pipeline necessary
- base cost multiplied with transporting higher temperature geothermal fluids

23 wells x 3960 feet = 91,080 feet of pipe
91,080 x $74.00/lin. ft. = $6,739,920
mainpipeline 6 miles (21,120 feet) x $363.00/lin. ft. =$11,499,840
$6,739,920 + $10,866,240 = 17,606,160
$17,606,160 x 1.1 = 19,366,776

These costs are slightly greater in the building block due to programming requirements. Discrepancies between the original calculations and the costs appearing in the building block are insignificant and the result of programming requirements.

The selection of average distances and hence the amount of pipeline is somewhat arbitrary. Distances from the well head to a main pipeline or user vary greatly in all existing applications of geothermal energy. Pipeline cost was taken directly from Geothermal Energy Potential for District and Process Heating Applications in the U.S. - An Economic Analysis, published in August 1977 by Batelle Pacific Northwest Laboratories. It should be noted that the amount of pipe necessary includes the pipe used to transport fluids that are reinjected.

d. Building Block-D4.11 Environmental Control and Water Purification

These costs are the low, the high, and a middle point taken from a wide range of costs originally generated for this building block. The costs are a percentage of drilling of productions. Low and middle temperature resevoirs incur environmental control and water purification costs that are 20 percent, 25 percent, or 30 percent of overall drilling and production costs; high temperature costs are assessed to incur costs that are 25 percent, 30 percent, or 35 percent of overall drilling and production costs. The percentage figures were derived from a base system costed out by the Lawrence Livermore Laboratory study. Resevoirs vary so significantly in solvent minerals and pollutants, the use of a percentage figure was the only reasonable way possible to include these costs into an overall geothermal system.

High Temperature

.25 x 18,800,000 = 4,700,000

.30 x 18,800,000 = 5,640,000

.35 x 18,800,000 = 6,580,000

Medium Temperature

.20 x 9,800,000 = 1,960,000

.25 x 9,800,000 = 2,450,000

.30 x 9,800,000 = 2,940,000

Low Temperature

.20 x 4,200,000 = 840,000

.25 x 4,200,000 = 1,050,000

.30 x 4,200,000 = 1,260,000

e. Building Block-E4.11 Flow Maintenance

This building block is the cost of drilling and using reinjection wells. Different ratios were used to establish the amount of reinjection wells necessary for each producing well. The ratios used are 1 reinjection for every two producing wells, 1 reinjection for every four producing wells, and 1 reinjection for every 6 producing wells. A well cost of $97.00 a foot were used. Pipeline cost was included in the transportation building block. The well costs were obtained from the Stanford Research Institute and Batelle Pacific Northwest Laboratories reports quoted above. The $97.00/ft. figure was concluded to be the most accurate representation of the different well costs in question.

High Temperature

cost	
$1,358,000	1 reinjection for 2 producing wells
$ 679,000	1 reinjection for 4 producing wells
$ 679,000	1 reinjection for 6 producing wells

Medium Temperature

$2,328,000	1 reinjection for 2 producing wells
$1,164,000	1 reinjection for 4 producing wells
$1,164,000	1 reinjection for 6 producing wells

Low Temperature

$5,820,000	1 reinjection for 2 producing wells
$2,910,000	1 reinjection for 4 producing wells
$1,940,000	1 reinjection for 6 producing wells

f. Building Block-F4.11 Distribution to End Users

The distribution costs in this building block represent the cost of distributing geothermal fluid to 20 end users at distances of 1, 10 and 25 miles. The pipe used is the same 12 inch diameter 74.00/ft. pipe used in the transportation building block.

1 mile (5280 feet) x $74.00/ft. = $390.720
$390,720 x 20 = $7,814,400

10 miles (52,800 feet) x $74.00/ft. = $3,907,200
$3,907,200 x 20 = $78,144,000

25 miles (132,000 feet) x $74.00/ft. = $9,768,00
$9,768,000 x 20 = $195,360,000

g. Building Block-G4.11 Distribution Heat Loss Cost Multiplier

This building block attempts to capture the increase in costs due to energy losses resulting from the transportation of geothermal fluids. It is a multiplier, because all costs increase as more energy is needed from a field to account for energy losses incurred in transportation.

The relationship of topography, ambient air temperature, fluid energy content, and the design specifications of a pipeline determine exactly how much of an energy loss there will be for a given system. Data is extremely site specific and often unreliable; this multiplier is based partly on the above mentioned Batelle Pacific Northwest Laboratories study and in house engineering analysis.

h. Building Block-H4.11 Indirect Capital Cost Multiplier

This component is documented in the fossil energy technologies section of this appendix. The actual multipliers used are slightly larger than those used for other ISTUM technologies for the following reasons;

1) most if not all geothermal reservoirs are on federal land. It was assumed that the extra cost of constructing an industrial facility on federal

land was not captured by the other indirect capital cost multiplier (H 8.11).

2) Virtually all geothermal resevoirs are in fairly remote areas, while at least half of all manufacturing facilities in the United States are located in or around urban centers. The isolation of geothermal facilities must undoubtedly lead to higher indirect capital costs.

Non-Cost Related Information

Year Available - DOE Acceleration

Geothermal steam fed electric power plants have been on line for at least fiften years in the United States, and industrial plants use flashed geothermal hot water can be found in different parts of the world, so it is safe to state that geothermal steam is available and considered by industry to be technically feasible. It is also safe to assume that DOE policies will accelerate the adaptation of geothermal technology, mainly due to the geothermal loan guarantee program. The only geothermal industrial facility in the United States, an onion washing and dehydration facility, is being built with a loan guarantee from DOE.

Fuel Efficiencies

The fuel used is geothermal fluid, which has no cost. System energy efficiencies were included in the cost distribution, for even a drastic change in the stated fuel efficiency (from 1.0 to .05) would not affect the technology's cost, because the fuel has no cost.

Size Range

Geothermal steam can be used at any size or load factor, and is more economical as load factor increases.

Maximum Market Fraction

It must be stressed that data necessary for the determination of geothermal steam maximum market fraction is simply not available. When one takes into account the measured potential of Known Geothermal Resource Areas (KGRAs) and Potential Geothermal Resource Areas (PGRAs), the temperature and purity needed for industrial steam and the geographical isolation of virtually all resevoirs, it becomes clear that the potential market for geothermal steam is quite small. Added to these problems is the fact that at least half of all manufacturing facilities in the United States are located in or near urban areas, making the installation of pipe prohibitively expensive.

The two and one half percent figure is qualified by the data coding letter D, meaning the figure is a guesstimate, at best. The real maximum fraction might be twice that size, but even then it is small, and a significant error in this estimate should not seriously effect the overall model results.

Construction Period

This period of time includes the last two years of exploration and the three years needed for construction. Data on lead times and construction periods can be found in many places, the SRI model quoted above being a good source. Most of these studies have similar estimates for exploration and construction time. The first few years of exploration are expensed differently than the costs associated with the final development of a field although these preliminary exploration costs eventually become part of total system cost.

Physical Life

The physical life of the whole system is 30 years, although, because no major energy conversion facilities are involved, this is not due to the physical depreciation of the equipment. Resevoir lives are usually measured in 30 years, and this is what was chosen for the model. It should be noted that resevoirs are measured as such mainly because the life of an electric power plant is thirty years. Should data concerning the life of geothermal resevoirs ever appear in different form, the physical life of a geothermal industrial steam system may be different.

Well life is not thirty years. Replacement wells are needed every ten years, and the cost of these wells is included in the O&M cost.

Applicable SICs

No data has been discovered that shows a industry to be technically unable to use geothermal steam.

GENERAL INFORMATION FOR SOLAR AND GEOTHERMAL TECHNOLOGIES

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TECH ID	TECHNOLOGY NAME	YEAR AVAIL	FUELS USED	FUEL SHARE (1ST FUEL)	FUEL_EFFECIENCY COMBUSTN	TRANSMIS	FINL USE	SIZE_RANGE (MMBTU/HR) LO	HI	LOAD_RANGE (HRS/YR) LO	HI	_MAXIMUM_FRACTION INCREMENTL	RETRO FIT	CONSERVATN
3.11	SOLAR CONCENTRA	1980	8 2	0.72	1.00	1.00	1.33	2	200	400	4001	0.30	0.00	1.00
3.112	SLR FLAT PLATE	1977	8	1.00	1.00	1.00	1.00	5	100	1000	4000	0.80	0.00	1.00
3.21	SOLAR CONC/FOSS	1980	2 8	0.62	1.00	1.00	1.44	¯1	¯1	4002	7000	0.30	0.00	1.00

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TECH ID	TECHNOLOGY NAME	SERV SECT	____DATA_QUALITY____ MAX FRAC	COST	ENER SAVE	ACCELER	CONST PER (YRS)	PHYS LIFE (YRS)	DOE ACCEL (YRS)	LAST UPDATED
3.11	SOLAR CONCENTRA	1	C	C		C	0.5	20	3	MAR 22, 1978 1:40:30 PM
3.112	SLR FLAT PLATE	12	C	B		B	0.3	20	0	MAR 23, 1978 2:18:31 PM
3.21	SOLAR CONC/FOSS	1	C	C		C	1.0	20	3	MAR 23, 1978 2:19:00 PM

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APPLICABLE INDUSTRIES (MODIFIED SIC CODES)

TECH ID	TECHNOLOGY NAME	20	21	22	23	24	25	26	27	28	29	30	31	32	331	3334	334	34	35	36	37	38	39	01	02	10	14
3.11	SOLAR CONCENTRA	1	1	1	1	1	1	1	1			1	1	1				1	1	1	1	1	1	1	1	1	1
3.112	SLR FLAT PLATE	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.21	SOLAR CONC/FOSS	1	1	1	1	1	1	1	1			1	1	1				1	1	1	1	1	1	1	1	1	1

GENERAL INFORMATION FOR SOLAR AND GEOTHERMAL TECHNOLOGIES

PAGE 1
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TECH ID	TECHNOLOGY NAME	YEAR AVAIL	FUELS USED	FUEL SHARE (1ST FUEL)	FUEL EFFECIENCY COMB USTN	TRAN SMIS	FINL USE	SIZE RANGE (MMBTU/HR) LO	HI	LOAD RANGE (HRS/YR) LO	HI	MAXIMUM FRACTION INCRE MENTL	RETRO FIT	CONSE RVATN
4.11	GEOTHERMAL	1977	10	1.00	1.00	1.00	1.00	¯1	¯1	¯1	¯1	0.02	0.00	0.00

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TECH ID	TECHNOLOGY NAME	SERV SECT	DATA QUALITY MAX FRAC	COST	ENER SAVE	ACCE LER	CONST PER (YRS)	PHYS LIFE (YRS)	DOE ACCEL (YRS)	LAST UPDATED
4.11	GEOTHERMAL	1	D	C		C	5.0	30	3	APR 6, 1978 2:51:13 PM

PAGE 3
APR 10, 1978 2:22:09 PM

APPLICABLE INDUSTRIES (MODIFIED SIC CODES)

TECH ID	TECHNOLOGY NAME	20	21	22	23	24	25	26	27	28	29	30	31	32	331	3334	334	34	35	36	37	38	39	01	02	10	14
4.11	GEOTHERMAL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

SOLAR AND GEOTHERMAL TECHNOLOGY SPECIFICATION

BUILDING BLOCK COEFFICIENTS

PRINTED APR 10, 1978 10:38:52 AM

TECH ID 3.11

UPDATED MAR 22, 1978 10:24:18 AM

	BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A	3.11	2.00	0.50	2.50
B	3.11	2.00	0.50	2.50
C	3.11	2.00	0.50	2.50
D	3.11	2.00	0.50	2.50
E	3.11	2.00	0.50	2.50
F	3.11	1.00	1.00	1.00
G	3.11	1.00	1.00	1.00
H	8.11	1.00	1.00	1.00

TECH ID 3.112

UPDATED MAR 23, 1978 2:50:48 PM

	BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A	3.112	2.50	1.00	4.00
B	3.112	2.50	1.00	4.00
C	3.112	2.50	1.00	4.00
G	3.11	1.00	1.00	1.00
H	8.11	1.00	1.00	1.00

TECH ID 3.21

UPDATED MAR 23, 1978 2:49:33 PM

	BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A	3.11	2.00	0.50	2.50
B	3.11	2.00	0.50	2.50
C	3.11	2.00	0.50	2.50
D	3.11	2.00	0.50	2.50
E	3.11	2.00	0.50	2.50
F	3.11	1.00	1.00	1.00
G	3.11	1.00	1.00	1.00
H	8.11	1.00	1.00	1.00

SOLAR AND GEOTHERMAL TECHNOLOGY SPECIFICATIONS

BUILDING BLOCK COEFFICIENTS
PRINTED APR 10, 1978 2:16:54 PM

TECH ID 4.11
UPDATED MAR 17, 1978 11:06:18 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 4.11	0.05	0.50	2.50
B 4.11	0.05	0.50	2.50
C 4.11	0.05	0.50	2.50
D 4.11	0.05	0.50	2.50
E 4.11	0.05	0.50	2.50
F 4.11	0.05	0.50	2.50
G 4.11	1.00	1.00	1.00
H 4.11	1.00	1.00	1.00

SOLAR AND GEOTHERMAL BUILDING BLOCKS

BUILDING BLOCKS
PRINTED APR 10, 1978 2:27:59 PM

ID: A 3.11
NAME: COLLECTORS
LAST UPDATED MAR 13, 1978 1:49:27 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE 5
FRACTION OF COSTS FOR O+M: 0.017
FREQUENCY AND COST DATA:

1.000	4,062.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: A 3.112
NAME: FLAT PLATE COLLECTORS
LAST UPDATED MAR 14, 1978 11:04:21 AM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 10
TYPE 5
FRACTION OF COSTS FOR O+M: 0.02
FREQUENCY AND COST DATA:

1.000	493.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: B 3.11
NAME: SITE PREP
LAST UPDATED MAR 13, 1978 2:07:05 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE 5
FRACTION OF COSTS FOR O+M: 0.01
FREQUENCY AND COST DATA:

0.250	65.000
0.500	78.000
0.250	90.000
0.000	0.000

ID: B 3.112
NAME: FLAT PLATE INSTALLATION
LAST UPDATED MAR 22, 1978 10:28:16 AM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 10
TYPE 5
FRACTION OF COSTS FOR O+M: 0.02
FREQUENCY AND COST DATA:

0.500	411.000
0.400	821.000
0.100	1,230.000
0.000	0.000

BUILDING BLOCKS
PRINTED APR 10, 1978 2:29:21 PM

ID: C 3.11
NAME: INSTALLATION
LAST UPDATED MAR 24, 1978 11:00:59 AM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE 5
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.400	5,500.000
0.450	10,270.000
0.150	19,833.000
0.000	0.000

ID: C 3.112
NAME: STORAGE
LAST UPDATED APR 6, 1978 2:39:18 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 10
TYPE 5
FRACTION OF COSTS FOR O+M: 0.01
FREQUENCY AND COST DATA:

0.100	74.000
0.300	136.000
0.600	184.000
0.000	0.000

ID: D 3.11
NAME: FOSSIL BACK UP
LAST UPDATED MAR 13, 1978 1:58:55 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE 5
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

1.000	467.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: E 3.11
NAME: FEEDWATER AND UTILITIES
LAST UPDATED MAR 13, 1978 2:08:53 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE 5
FRACTION OF COSTS FOR O+M: 0.11
FREQUENCY AND COST DATA:

0.200	0.000
0.600	31.000
0.200	146.000
0.000	0.000

BUILDING BLOCKS
PRINTED APR 10, 1978 2:31:00 PM

ID: F 3.11
NAME: TEMPERATURE
LAST UPDATED MAR 13, 1978 2:10:00 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE M
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.200	1.000
0.250	1.120
0.250	1.240
0.300	1.350

ID: G 3.11
NAME: INSOLATION MULTIPLIER
LAST UPDATED MAR 25, 1978 11:31:44 AM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE M
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.220	1.000
0.170	1.350
0.320	1.970
0.290	3.000

ID: H 8.11
NAME: INDIRECT CAPITAL COSTS (ENGIN, CONTIN)
LAST UPDATED MAR 12, 1978 7:08:23 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 0
TYPE M
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.550	1.300
0.350	1.400
0.100	1.500
0.000	1.650

BUILDING BLOCKS
PRINTED APR 10, 1978 2:18:22 PM

ID: A 4.11
NAME: EXPLORATION AND DISCOVERY
LAST UPDATED MAR 17, 1978 11:01:20 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 2000
TYPE 5
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

1.000	35,086.000
0.000	0.000
0.000	0.000
0.000	0.000

ID: B 4.11
NAME: DRILLING AND PRODUCTION
LAST UPDATED MAR 13, 1978 2:23:03 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 2000
TYPE 5
FRACTION OF COSTS FOR O+M: 0.117
FREQUENCY AND COST DATA:

0.500	4,200.000
0.400	9,800.000
0.100	18,800.000
0.000	0.000

ID: C 4.11
NAME: TRANSPORTATION
LAST UPDATED MAR 13, 1978 2:24:03 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 2000
TYPE 5
FRACTION OF COSTS FOR O+M: 0.078
FREQUENCY AND COST DATA:

0.650	3,470.000
0.250	12,100.000
0.100	19,400.000
0.000	0.000

ID: D 4.11
NAME: ENVIR CONTROL AND WATER PURIFICATION
LAST UPDATED MAR 24, 1978 11:01:58 AM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 2000
TYPE 5
FRACTION OF COSTS FOR O+M: 0.117
FREQUENCY AND COST DATA:

0.500	1,170.000
0.350	2,830.000
0.150	4,240.000
0.000	0.000

BUILDING BLOCKS
PRINTED APR 10, 1978 2:20:39 PM

ID: E 4.11
NAME: FLOW MAINTENANCE
LAST UPDATED MAR 24, 1978 11:02:40 AM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 2000
TYPE S
FRACTION OF COSTS FOR O+M: 0.117
FREQUENCY AND COST DATA:

0.420	680.000
0.450	2,090.000
0.130	5,880.000
0.000	0.000

ID: F 4.11
NAME: DISTRIBUTION TO END USERS
LAST UPDATED MAR 17, 1978 11:02:26 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 2000
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

0.300	7,820.000
0.500	78,140.000
0.200	195,360.000
0.000	0.000

ID: G 4.11
NAME: DISTRIBUTION HEAT LOSS COST MULTIPLIER
LAST UPDATED MAR 17, 1978 11:03:50 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 2000
TYPE M
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.300	1.110
0.500	1.250
0.200	1.330
0.000	0.000

ID: H 4.11
NAME: INDIRECT CAPITAL COST MULTIPLIER
LAST UPDATED MAR 17, 1978 11:07:22 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 2000
TYPE M
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.200	1.400
0.500	1.500
0.300	1.650
0.000	0.000

CHAPTER VI

CONSERVATION TECHNOLOGIES

The specifications of the conservation technologies that compete in the ISTUM model are presented here. Thirty three conservation technologies are represented in ISTUM. The diversity of these conservation technologies made their specification in a form compatible with ISTUM very difficult. Many of the conservation technologies incorporate difficult to evaluate but significant non-energy factors related to environmental control, production capacity, and institutional relationships. These issues are discusses more fully in Volume I, chapter II.

Technology name: Boiler Air/Fuel Control
Heater Air/Fuel Control
Technology I.D.: 2.11, 2.113, 2.12, 2.13

The boiler air/fuel control and heater air/fuel control technologies represent the DOE research effort into instrument systems to maximize fuel combustion efficiency. The current program is based upon micro-processor controls supported by a stack gas analyzer and possible spectral flame analyzers at each burner. By minimizing excess air and operating major combustion equipment at near stoichiometric levels, fuel savings of 1 to 2 percent are possible.

Based upon data from the DOE project manager, EEA placed the air/fuel control technologies into the steam, clean/intermediate direct heat, dirty direct heat, and non-coal indirect heat service sectors in all industries. The technology specifications for these monitoring devices were based upon a 4 burner 200,000 lb./hr. boiler. EEA accepted the DOE project manager's judgment that the costs of non-boiler applications could be reasonably represented by this single specification because of the "bolt-on" nature of stack monitors and spectral analyzers. The actual energy savings potential in non-boiler applications would probably vary greatly and be more uncertain.

Service Demand Displacement

Based upon a 2 percent energy savings the service demand relief for a 200,000 lb/hr. boiler is:

Energy Savings	x	Fuel Efficiency	x	Boiler Size	=	service demand displacement
.02	x	.82	x	200×10^6 Btu/hr	=	3.28 MMBtu/hr

Equipment Cost

The air/fuel control equipment includes a microprocessor, stack gas analyzer, and possibly additional spectral analyzers for individual burners. Differences in installation cost will probably be the single largest factor contributing to total cost variations. EEA assumed the proposer's cost of $115,000 for a 200,000 lb/hr. air/fuel control system was based upon an ideal boiler application. Total installed cost in 90 percent of all applications (Blocks A2.11, A2.12) was expected to fall between $115,000 to $180,000.

Operating and maintenance costs for air/fuel controls was expected to be about 4 percent of total installed cost.

The air/fuel control technology was placed in four service sectors and could compete for service demand in all industrial categories. The equipment costs were linear scaled to ISTUM size categories. No technical restrictions for size or load appeared to be applicable.

Maximum Market Calculation

For most conservation technologies, the maximum market calculation incorporates information on a specific industry structure, estimated energy savings, and technical limitations. EEA has specified the air/fuel control technologies for 4 service sectors and all industries, and does not find any applicable technical limitations to this specification. Therefore, the maximum market fraction is based on just the potential energy savings, estimated to be 2 percent for air/fuel control.

Data Quality

The capital costs, energy savings, and market potential for boiler air/fuel controls could be verified by engineering calculations and numerous published reports of microprocessor based combustion control equipment. The potential energy savings for non-boiler applications was not documented and included considerable uncertainty in technical areas. The technology data was generally considered at the "B" quality code, with the energy savings potential of non-boiler applicatons class as a "C" code.

Technology name: Poultry Process Modification
Technology I.D.: 2.31

The conservation measures for the poultry processing industry that are supported by this DOE project include energy audits, simple housekeeping measures, and capital investments for heat recovery equipment. The major investments for a poultry plant would include modification of the scald tank, installation of heat recuperators on hot process water over flows, and adapting a heat exchanger to the refrigerator units to preheat water. The overall impact of this DOE program would be a reduction in the service demand for steam in the food industry (SIC 20).

Approximately 90 percent of all poultry processing is concentrated in 250 dual eviscerating plant modules located in the 175 largest plants in the United States. USDA data indicates that only 50 of these production modules operate for two shifts a day, or about 4000 hours/year. Since the smallest load range for steam in ISTUM is 4,000 hours/year, EEA used the double shift poultry module for technology specification.

Service Demand Displacement

EEA estimated the following energy savings and capital cost break down for double shift poultry plants:

Component	Cost	Energy Savings 10^9 Btu/year
Initial housekeeping	$10,000	19.2
Modified scalder tank	$35,000	7.5
Heat recuperators	$35,000	8.9
Modified cleaning system	$ 7,000	3.6
TOTAL	$87,000	39.2

Based upon a 39.2 x 10^9 Btu/year energy savings in the poultry industry the steam service demand displacement at 4000 hours/year is:

$$\frac{\text{energy savings x fuel efficiency}}{\text{hours of operation}} = \text{service demand displacement}$$

$$\frac{39.2 \times 10^9 \text{ Btu/year} \times .82}{4000 \text{ hr/year}} = 8.036 \text{ MMBtu/hr}$$

Equipment Cost

The equipment cost for modifying the poultry process is based upon the proposer's component breakdown identified in the table above. The proposer indicated that the cost for scalder modification could be lower for some plant configurations. EEA assumed the ideal application would cost $80,000, and the 30 percent of all plants would be modified for a cost of $80,000 to $87,000. An additional 50 percent of all applications would face a total charge of $87,000 to $94,000. This relatively tight distribution of cost is supported by the simple nature of the proposed modifications.

Operating and maintenance costs were anticipated to be about 5 percent of installed capital cost. A linear scale factor of 6.25 was used to match the technology cost distribution to the 50 MMBtu/hr ISTUM steam size category.

Size and Load Ranges

Detailed information on the operating characteristics of poultry processing plants indicated that placing this technology package in the largest steam size and load categories was inappropriate. EEA therefore restricted the competition of poultry process modification to the ISTUM 50 MMBtu/hr size and 4000 hour/year load range.

Maximum Market Fraction

The 50 double shift modules can each save 39.2 x 10^9 Btu/year by adopting this technology package. The 200 single shift modules are incorporated into the maximum service demand displacement calculation by counting them as 100 double shift plants. The maximum annual displacement of steam service demand is therefore:

$$\left(\left(.5 \times \text{single shift modules}\right) + \text{double shift modules}\right) \times \text{module energy savings} \times \text{fuel efficiency} = \text{maximum service demand displacement}$$

$$((.5 \times 200) + 50) \times 32.9 \times 10^9 \times .82 = 4.8 \times 10^{12}$$

The ISTUM allocation of size and load ranges for the food industry limits the competition of poultry process modification (specified at only 50 MMBtu/hr and 4000 hr/year) to only 45 percent of the steam service demand in the food industry. Since the calculation of maximum service demand displacement was based upon specific plant data that already considered size and load constraints, the final maximum market calculation must be adjusted accordingly.

$$\frac{\text{maximum service demand displacement}}{\text{size/load constraint factor} \times \text{industry service demand}} = \text{maximum market fraction}$$

$$\frac{4.8 \times 10^{12} \text{ Btu/year}}{.45 \times 329.0 \times 10^{12} \text{ Btu/year}} = .0324$$

Data Quality

The technical specification of poultry process modification was supported by detailed component cost breakdowns and engineering calculations of energy savings. EEA was able to verify this data using our own engineering calculations. Although the USDA data on the market for this technology was very good, the modeling problems associated with converting single shift facilities into ISTUM compatible units indicated that a "C" quality code for maximum market fraction was appropriate.

Technology name: Headbox for Paper

Technology I.D.: 2.51

This technology is based upon a modification to the headbox in the papermaking process. The goal of the process change is to increase the solid content of paper slurry from .5 to 2.0 percent, which would decrease the steam service demand in the drying cycle. The project data is based upon paper making units over 200 inches, accounting for approximately 75 percent of total production.

Service Demand Displacement

The proposer claims the headbox modification can save $.1 \times 10^{12}$ Btu/year. Using ISTUM assumptions about hours of operation and fuel efficiencies for the steam service sector in the paper industry, the hourly service demand displacement is:

$$\frac{\text{energy savings x fuel efficiency}}{\text{hours of operation}} = \text{service demand displacement}$$

$$\frac{.1 \times 10^{12} \times .82}{7000} = 11.7 \text{ MMBtu/hr.}$$

Equipment Cost

The ISTUM equipment cost distribution was based upon the proposer's point estimate for retrofit applications. Since the DOE project manager indicated that this technology would be applicable to only 250 existing facilities. EEA assumed the modification costs would depend upon unique plant designs. Under the circumstances total costs might rise significantly beyond the propers estimate for an ideal applications. EEA estimated that 50 percent of all applications (Block A 2.51) would cost between $700,000 and $900,000. An additional 40 percent of the applications would cost $900,000 to $1,200,000. Operating and maintenance charges were anticipated to be equal to the conventional system. A linear scale factor of 21.37 was employed to match the 250 MMBtu/hr ISTUM size category in the steam service sector.

Size and Load Range

The improved headbox is designed for only the largest paper forming facilities. Since equipment cost and technical performance at the 50 MMBtu/hr size and the 4000 hours/year load range was not appropriate, EEA restricted this technology to steam demand at 250 MMBtu/hr operating 7000 hours/year.

Maximum Market Fraction

The proposer indicated that the current total market for this headbox modification was 250 paper forming units. The maximum service demand displacement in 1978 is therefore:

energy savings	x	fuel efficiency	x	total units	=	maximum service demand displacement
$.1 \times 10^{12}$ Btu/unit/yr	x	.82	x	250 units	=	20.5×10^{12} Btu/year

When size and load restrictions are used in technology specification, the maximum market fraction calculation may need to be adjusted. Due to ISTUM size and load assumptions, the restricted headbox technology can compete for only 56 percent of the steam service sector in the paper industry. Since the prior maximum service demand displacement already recognized the technical limitations for this process modification, the ISTUM maximum market must be increased to compensate for the restriction:

$$\frac{\text{maximum service demand displacement}}{\text{size/load restriction} \times \text{industry service demand}} = \text{maximum market fraction}$$

$$\frac{20.5 \times 10^{12} \text{ Btu/year}}{.56 \times 937.4 \times 10^{12} \text{ Btu/year}} = .039$$

Data Quality

Since this technology was not supported by equipment component breakdowns or any fuel scale demonstration, EEA gave the cost and energy savings a "C" quality code. The maximum market fraction is supported by slightly better data on existing paper making facilities and was rated as a "B".

Technology name: Pulp Paper Characterization
Technology I.D.: 2.61

This project is based upon the development by the National Bureau of Standards of a image analysis device to characterize pulp paper. The benefits of this technology are predicted to be: (1) increased recycling of poorly utilized mixed pulp papers, (2) the optimizing of existing recycling processes by accurately measuring the pulp quality prior to paper making, and (3) increased control and better utilization of materials in the virgin pulp industry.

Service Demand Displacement

The energy savings claimed by the proposer include 45 x 10^9 Btu/year of oil or coal and 27 x 10^9 Btu/year of electricity. EEA made numerous phone calls to the proposer to try and document the sources of claims but was unable to determine their origin. Based upon an average consumption of 20 to 30 million Btu/ton for paper, the proposer claims a 10-12 percent energy savings for this paper technology. Assuming the energy savings are obtained by (1) eliminating test runs to verify paper quality and (2) minimizing resident time in pulp baths, the service demand displacement for the image analysis equipment is:

$$\frac{\text{fuel efficiency} \times \text{steam demand relief} + \text{fuel efficiency} \times \text{electric energy savings}}{\text{hours of operation}} = \text{service demand displacement}$$

$$\frac{(.82 \times 45 \times 10^9) + (.285 \times 27 \times 10^9)}{7000} = 6.37 \text{ MMBtu/hr}$$

Equipment Cost

The proposer of this technology expressed considerable uncertainty at the eventual cost for a fiber characterization unit. Virtually no analysis or engineering calculations of cost have been performed. The proposer indicated a target capital cost of $110,000 for one image analysis unit. EEA guessed that installed costs (Block A2.61) for the full spectrum of applications could range from $110,000 to $160,000.

Operating and maintenance was estimated to be 5 percent of capital costs. The 6.37 MMBtu/hr service demand displacement required that the pulp characterization capital cost be linearly scaled to ISTUM steam service sector sizes, 50 and 250 MMBtu/hr.

Maximum Market Fraction

The proposer estimated a market for 500 pulp image analysis devices. Based upon the hourly service demand displacement and this market estimate, the maximum service demand relief is:

$$\text{units sold} \times \text{hourly service demand displacement} \times \text{hours of operation} = \text{maximum service demand displacement}$$

$$500 \text{ units} \times 6.37 \text{ MMBtu/hr} \times 7000 \text{ hrs/yr.} = 22.3 \times 10^{12} \text{ Btu/yr.}$$

The ISTUM maximum market fraction is therefore:

$$\frac{\text{maximum service demand displacement}}{\text{industry service demand}} = \text{maximum market fraction}$$

$$\frac{22.3 \times 10^{12} \text{ Btu/yr}}{937.4 \times 10^{12} \text{ Btu/yr}} = .0238$$

Data Quality

Up to this time, the work on this DOE project has been directed at technical issues and has not included an explicit analysis of market potential, equipment cost, or energy savings. The proposer could not document the early estimates in these areas. Because of this lack of supporting documentation, the data quality for maximum market fraction and cost were coded as "C". The poorly documented energy savings of this technology, possible involving multiple service sectors presents difficult modeling problems and is coded as a "D".

Technology name: Hyperfiltration

Technology I.D.: 2.71

The technology data for HYPERFILTRATION is drawn from a joint DOE/EPA project for the closed cycle operation of textile plants. With this technology, hot process water is cleaned and reused many times, reducing the demand for steam. In addition, the filtration process can reduce pollution control costs, decrease water consumption, and provide an opportunity to recover chemicals and dyes.

<u>Service Demand Displacement</u>

The ISTUM specification is based upon a 30 gallon/minute filtration unit recycling 90 percent of 180^{o}F water. For a unit operating at 7,000 hours/year, the fuel savings is expressed as follows:

process bath recycling efficiency		filter capacity		temperature difference of water		energy consumption to heat water		energy savings per unit
.9	x	1.26×10^6 gal/yr/unit	x	130 ^{o}F	x	8.34	=	13×10^9 Btu/yr/unit

The service demand of this unit is 1.5 MMBtu/hr based upon 7000 hr/year and an 82 percent efficiency in raising steam. To account for the electricity consumption of pumps, this service demand rating was lowered to 1.2 MMBtu/hr.

<u>Equipment Cost</u>

The capital cost frequency of the hyperfiltration unit (building block A 2.71) was based upon a revised point estimate from the DOE project manager.

EEA assumed that the project manager's estimate of $133,000 for a hyperfiltration unit reflected a favorable application. For the entire textile industry, EEA estimate that 50 percent of the applications would fall between $133,000 and $150,000 and about 40 percent of the applications would cost between $150.000 and $180,000. The non-energy costs are reflected in the annual operating and maintenance charge. EEA estimated the annual chemical recovery and water pollution control benefits to range between $26,000 and $41,000 or 17 to 30 percent of the capital costs of an average hyperfiltration unit. With a typical O&M charge of $15,000 or 10 percent of the average unit cost, the hyperfiltration unit provides an average net savings of 12 percent of the capital cost each year.

Although the filtration unit has a 1.2 MMBtu/hr service demand rating, it will compete with other technologies to displace steam demand in either the 50 and 250 MMBtu/hr categories. Based upon the modular nature of the technology, EEA assumed that a linear scaling of the capital costs to these sizes was appropriate.

Maximum Market Fraction

The maximum market fraction for the hyperfiltration technology could only be estimated indirectly with poorly documented data. EEA assumed that one third of all water consumed in the textile industry (100 x 10^9 gallc·s per year in one EPA estimate) was at 180°F. The total number of filtration units required to handle this water ..s:

$$\frac{\text{hot water in textile industry}}{\text{hyperfiltration unit capacity}} =$$

$$\frac{.33 \times (100 \times 10^9 \text{ gallons/year})}{30 \text{ gal/min} \times 60 \text{ min/hr} \times 7000 \text{ hr/yr.}} = 2645 \text{ units}$$

The maximum service demand displacement for the entire textile industry is:

$$2645 \text{ units} \times 1.2 \text{ MMBtu/hr} \times 7000 \text{ hr/yr} = 22 \times 10^{12} \text{ Btu/yr}$$

The ISTUM maximum market fraction is therefore:

$$\frac{\text{maximum technology service demand displacement}}{\text{applicable industry service demand}} = \text{maximum market fraction}$$

$$\frac{22 \times 10^{12}}{93.6 \times 10^{12}} = .237$$

Data Quality

The energy savings of this technology could be partially verified by an engineering calculation of the waste water stream. However the equipment costs and maximum market fraction were based upon more questionable data. The capital cost specification relies heavily on the point estimates provided by the proposer and project managers point estimates, and the ISTUM logic must be stretched to incorporate non-energy credits. The capital costs in ISTUM were not supported by data from a full scale demonstration unit or engineering cost calculations. The maximum market fraction relies on questionable assumptions about the volume and temperature distribution of process water in the textile industry. Therefore this technology was given a "D" code for maximum market fraction and a "C" code on costs. The energy savings was classified as "B" quality data.

Technology Name: Low Level Heat Pumps
Technology I.D.: 2.81

This DOE sponsored project is designed to reclaim waste heat from industrial processes and convert it to steam. The technology is based upon a reverse Rankine type of refrigeration cycle. The heat pump may be driven by a turbine that utilizes an independent waste heat steam.

Service Demand Displacement

The proposer indicated a potential fuel savings of 198 x 10^9 Btu/year with this low level heat pump. Based upon this data, the ISTUM service demand displacement is:

$$\frac{\text{fuel savings x fuel efficiency}}{\text{hours of operation}} = \text{service demand displacement}$$

$$\frac{198 \times 10^9 \text{ Btu/yr} \times .82}{7000 \text{ hr/yr}} = 23.2 \text{ MMBtu/hr}$$

Equipment Cost

The proposer provided the following breakdown of costs for the low level heat pump:

power recovery system	$303,000
piping, steam evaporator	$448,000
installation	$195,000
TOTAL	$846,000

EEA assumed that this cost represented an ideal application and that unique circumstances in some plants would almost double total cost. One half of all applications were estimated to fall between $750,000 and $950,000. An additional 40 percent of all applications were expected to cost from $950,000 to $1,300,000.

Operating and maintenance charges were estimated to annually cost about 7 percent of total capital cost. The 23.2 MMBtu/hr unit was linearly scaled to the ISTUM steam service sector size categories.

Maximum Market Fraction

The potential market for this technology is limited by the availability of waste heat sources and not potential applications of low temperature steam. EEA estimated that the low level heat pump was best suited for non-corrosive and high volume waste heat sources. Since very little documentation of waste streams is currently available, EEA conservatively estimated a five percent maximum market fraction. This represents the fraction of steam service demand for which an adequate waste heat source is available.

Data Quality Code

Since very little data is currently available on the characteristics of waste heat sources, and the market limits for the low level heat pump could not be accurately defined, EEA considered maximum market fraction to be a "D" data quality code. The energy savings of this technology while based upon engineering calculations was not verified by outside reviewers and was classed as "C" quality data. Due to the limited component breakdown of cost provided by the proposer, EEA judge the cost data was code "B".

Qualifications

The DOE project manager estimated a COP of 60 is technically feasible for this heat pump when the unit is driven by a waste heat turbine. Heat pumps without the turbine, operated with purchased electricity, may exhibit a COP of 15. The current ISTUM specification for the low level heat pump erroneously assumes a COP of 2.5. This error increases the charge for electricity consumed , resulting in an understatement of the true market potential for this heat pump.

Technology Name: Foam Fiber Technology

Technology I.D.: 2.91

The energy conservation potential of the DOE sponsored project is based upon a process change in the textile industry that will reduce the hot water required in fabric finishing. The conventional pad bath would be replaced with a novel foam process that could decrease the demand for steam.

Service Demand Displacement

Based upon the proposer's estimate of 25×10^9 Btu/year in energy savings, the service demand displacement of a foam fiber unit is:

$$\frac{\text{annual energy savings} \times \text{fuel efficiency}}{\text{hours of operation}} = \text{service demand displacement}$$

$$\frac{25 \times 10^9 \text{ Btu/yr} \times .82}{7000 \text{ hr/yr}} = 2.93 \text{ MMBtu/hr}$$

Equipment Cost

The ISTUM capital cost distribution for this technology is based entirely upon the proposers point estimate of the cost of an ideal application. EEA estimated that 90 percent of all applications would cost between $65,000 and $600,000. No differences were anticipated between operating and maintenance costs of the conventional and new system. The capital cost distribution (Block A2.91) was linear scaled to match the ISTUM sizes of 50 and 250 MMBtu/hr in the steam service sector.

Maximum Market Fraction

The market analysis for this technology is based upon an A.D. Little study which estimated that 674 technically compatible applications exist in the textile industry. Using this estimate, EEA calculated the maximum service demand displacement as follows:

$$\text{Total Market Units} \times \text{Unit Energy Savings} \times \text{Steam Fuel Efficiency} = \text{Maximum Service Demand Displacement}$$

$$674 \text{ units} \times 25 \times 10^{9} \text{ Btu/unit/yr} \times .82 = 13.82 \times 10^{12} \text{ Btu/yr.}$$

The ISTUM maximum market fraction is therefore:

$$\frac{\text{maximum service demand displacement}}{\text{textile steam service demand}} = \text{maximum market fraction}$$

$$\frac{13.82 \times 10^{12} \text{ Btu/yr}}{93.6 \times 10^{12} \text{ Btu/yr.}} = .1476$$

Data Quality

Since EEA was unable to confirm the technology specification through engineering calculations or an outside data source, the foam fiber project was given "C" quality codes.

Technology Name: Coal in Aluminum Remelt

Technology I.D.: 2.22

Conventional remelt furnaces in the aluminum industry are fired using oil or natural gas. This technology specification is based upon a 300×10^6 lb/year aluminum remelt plant that uses coal. The coal remelt process competes in the clean direct heat service sector for SIC 3334, the aluminum industry.

Service Demand Displacement

The proposer of this DOE sponsored project indicates that a 300×10^6 lb/year plant may consume 320×10^9 Btu/year. The service demand displacement of the coal remelt process may be calculated as follows:

$$\frac{\text{fuel savings} \times \text{fuel efficiency}}{\text{hours of operation}} = \text{service demand displacement}$$

$$\frac{32 \times 10^{10} \times .4}{6500} = 19.69 \text{ MMBtu/hr.}$$

Equipment Cost

The project data for this technology revealed a range of capital costs from $10 to 13 million. EEA estimated that half of all applications would cost between $10 and $11.6 million, with an additional 40 percent of all applications costing from $11.6 to 13.8 million.

The operating and maintenance charge was estimated to be $.83 $/MMBtu or about 2 percent of total capital costs. The coal in aluminum remelt was linearly scaled to the ISTUM clean direct heat service sector size categories.

Maximum Market Fraction

The DOE project manager estimated a potential market for 200 aluminum remelt plants. Based upon the hourly rating, the maximum service displacement is as follows:

hourly rating x hours/year x units = maximum service demand displacement

$$\underset{\text{Btu/hr}}{19.69 \times 10^{6}} \times \underset{\text{hr/yr}}{6500} \times \underset{\text{units}}{200} = \underset{\text{Btu/year/unit}}{25.6 \times 10^{12}}$$

The maximum market fraction is therefore:

$$\frac{\text{maximum service demand displacement}}{\text{ISTUM Direct Heat Service Demand in SIC 3334}} = \text{maximum market fraction}$$

$$\frac{25.6 \times 10^{12}}{38.7 \times 10^{12}} = .66$$

Data Quality

The energy savings, capital cost, and potential market for this technology was not veriied by outside review or detailed engineering calculations. Energy savings and cost data were considered "C" quality data, while the lack of corrobating data on the maximum market fraction indicated a "D" quality code was appropriate.

Technology Name: High Temperature Recuperator

Technology I.D.: 2.32, 2.33, 2.314, 2.315, 2.317, 2.319

Gases exiting high temperature industrial processes may be used to preheat incoming combustion air, saving as much as 30 percent of total fuel. The waste heat recovery research sponsored by DOE includes numerous high temperature recuperator projects. The ISTUM specification of recuperators is based upon a technical analysis of energy saving investments by the American Iron and Steel Institute.[1/]

High temperature recuperators were placed in 6 ISTUM service sectors: clean/intermediate direct heat, dirty direct heat, calcining, glass melting, ironmaking and steel reheating. The ISTUM specification is based upon AISI data on a soaking pit recuperator that uses a 1800°F waste gas stream to preheat combustion air from 70°F to 800°F.

Service Demand Displacements

The AISI report indicated that the soaking pit recuperator would save 24.03×10^9 Btu/year of fuel, assuming a 30 percent savings over a cold air condition. The service demand displacement of this recuperator is therefore:

$$\frac{\text{fuel savings} \times \text{fuel efficiency}}{\text{hours of operation}} = \text{service demand displacement}$$

$$\frac{24.03 \times 10^9 \text{ Btu/yr} \times .33}{5500} = 1.5 \text{ MMBtu/hr}$$

Equipment Cost

The equipment cost of the AISI recuperator was based upon an ideal application, involving no unusual installation costs.

1/ Handbook on Energy Conservation in the Steel Industry, American Iron and Steel Institute (AISI), May 26, 1976.

The total installed cost of $62,200 included the following components:

Radiation recuperator	41,500
Piping	6,500
Installation crane rental	2,000
Engineering	1,700
Labor	10,500
TOTAL	$62,200

EEA assumed that 50 percent of all recuperators would cost between $62,200 and $114,400. An additional 40 percent of all recuperators would cost between $114,400 to $167,000. This capital cost frequency is common to all cost building blocks (A2.32, A2.33, A2.314, A2.315, A2.317, A2.319) for recuperators in ISTUM.

Operating and maintenance charges are estimated by AISI at $4,000 per year, or 6.4 percent of installed cost. The recuperator cost, based upon a 1.5 MMBtu/year unit, was scaled to the ISTUM service demand sizes in each service sector.

Maximum Market Fraction

The maximum market fraction for recuperators is based upon a survey of waste heat recovery in 73 industry groups by Garrett Airesearch[1/]. The energy savings potential for 3-digit SIC using 85 percent effective recuperators was aggregated for each ISTUM service sector as follows.

1/ "Survey of Potential Energy Savings Using High Effectiveness Recuperators from Waste Heat Recovery from Industrial Flue Gases", Garrett Airesearch Manufacturing Company, October 15, 1977.

Service Sector 14 - Calcining

Garrett estimated a potential energy savings of 5.4 percent in calcining. Although this estimate was based only upon oil and gas fired kilns, about 30 percent of the calcining service sector, EEA assumed a maximum market fraction of .05 was reasonable.

Service Sector 15 - Glass melting

The Garrett survey identified the following fuel savings potential in glass melting:

SIC	Fuel Saving Potential	10^{12} Btu
3211	Flat Glass	9.39
3222	Glass Containers	13.19
3229	Pressed and Blown	6.00
3231	Products of Glass	2.39
GLASS MELTING		30.97

The maximum market fraction of recuperators in glass melting is therefore:

$$\frac{\text{Garrett estimated fuel savings}}{\text{ISTUM Glass melting fuel}} = \frac{30.97}{237.8} = .13$$

Service Sectors 17 Ironmaking
19 Steel Reheating

The Garrett Survey estimates the potential energy savings of recuperators in the steel industry. The industry could use recuperators for five different service sector: intermediate direct heat, dirty direct heat, ironmaking, steelmaking, and steel reheating. Since Garrett does not estimate potential energy savings by service sector, EEA assumed that energy savings from recuperators could be proportionally allocated to ISTUM service sectors based upon total service demand in each service sector.

SIC	Fuel Savings Potential	10^{12} Btu/yr
3312	Blast Furnace & Steel Mills	191.7
3315	Steel Wire	.75
3316	Cold Finished	--
3317	Steel Pipes & Tubes	2.73
Total Potential Energy Savings		195.18

Energy savings in service sector 2 or 3	- 48.53
Combined Service Sectors 17, 18, 19	146.65

The maximum market fraction for the combined service sectors is as follows:

$$\frac{\text{combined fuel savings}}{\text{iron making fuel} + \text{steel making fuel} + \text{steel reheating fuel}} = \text{maximum market fraction}$$

$$\frac{146.64 \times 10^{12} \text{ Btu/year}}{(141 + 115 + 577.9) \times 10^{12} \text{ Btu/yr.}} = .1758$$

Service Sector 2 Clean/Intermediate Direct Heat

3 Dirty Direct Heat

To obtain the maximum market fraction for service sectors 2 and 3, the Garrett energy savings had to be proportionally scaled between the service sectors and 4 applicable industrial groups. Table 1 summarizes the results of these calculations. The Garrett data is listed in Tables VI-1, VI-2, and VI-3.

TABLE VI-1

POTENTIAL FUEL SAVINGS IN DIRECT HEATS (10^{12} Btu/yr)

ISTUM Industry Classification	Service Sector 2 Clean/Intermediate Direct Heat	Service Sector 3 Dirty Direct Heat	
331	23.8	24.73	Proportionally allocated first from service sector 17 and 19 then between service sector 2 and 3
3334	24.6	3.79	From Table 2, proportionally allocated between service sectors 2 and 3
334	52.0	4.16	From Table 3, proportionally allocated between service sectors 2 and 3
34	17.69	--	From Table 4
TOTAL	118.09	32.68	POTENTIAL FUEL DISPLACEMENT
	680.2	183.8	ISTUM FUEL CONSUMPTION FOR THESE INDUSTRIES
	.1736	.1778	MAXIMUM MARKET FRACTION

TABLE VI-2

SIC-3334 Components

SIC		Fuel Savings Potential 10^{12} Btu
3334	Primary Aluminum	28.39
		TOTAL 28.39

TABLE 3 SIC-334 Components

SIC		Fuel Savings Potential 10^{12} Btu
3321	Gray Iron Foundries	2.77
3322	Malleable Iron Foundries	2.49
3324	Steel Investment Foundries	0.70
3325	Steel Foundries	1.21
3331	Primary Copper	6.80
3332	Primary Lead	0.84
3333	Primary Zinc	4.04
3351	Copper Rolling	8.54
3353	Aluminum Sheet	11.10
3354	Aluminum Extruded	2.96
3356	Nonferrous Rolling	3.79
3361	Aluminum Foundries	6.45
3362	Brass, Bronze, Copper Foundries	0.70
3369	Nonfer- Foundries	1.25
3398	Metal Heat Transfer	2.52
3399	Prim. Metal Products, NEC	--
	TOTAL	56.16

TABLE VI-3

SIC 34 Components

Sic		Fuel Savings Potential 10^{12} Btu
3432	Plumbing fittings	0.73
3443	Fab. Plate work Boiler	0.53
3462	Iron & Steel Forgings	12.50
3463	Non-Ferrous Forgings	1.39
3493	Steel springs, except wire	0.67
3631	Household cooking equip.	0.86
3728	Aircraft equip., NEC	1.01
	TOTAL	17.69

Data Quality

The overall quality of data on high temperature recuperators was very good. The ISTUM technical specification was supported by Garrett and AISI research. The energy savings potential in glass melting, calcining, ironmaking, steel reheating and the direct heats could be generally verified by engineering calculations.

Technology Name: Paper Pulp Sludge Drying
Technology I.D.: 2.43

Pulp sludges from a paper making plant are often disposed of by a two step process that includes mechanical dewatering and fuel-oil assisted incineration in hog fuel boilers. The pulp paper sludge drying alternative includes three steps: (1) sludge thickening, (2) solvent drying, and (3) steam recovery combustion. The benefits of this technology include a decrease in fuel oil consumption; the recovery of steam, and a reduction in the need for landfilling.

Service Demand Displacement

The service demand displacement for this technology was derived from the proposer's data for the new and conventional sludge drying process based upon a 50 ton/day dry weight plant. The conventional process consumers 3.63×10^9 Btu/yr of electricity in dewatering and 127.46×10^9 Btu/year of fuel in incineration. The new sludge drying system consumes 35.9×10^9 Btu/year of electricity but then produces steam, an equivalent of 20.40×10^9 Btu/year of fuel oil. The service demand displacement for this technology is the net energy savings for the 4 fuels:

$$\frac{115.8 \times 10^9 \text{ Btu/year}}{7500 \text{ Hours/Year}} = 15.44 \text{ MMBtu/hr}$$

Equipment Cost

The proposer estimated a total installed cost of $3 million for a 50 ton/day plant. EEA assumed this represented ideal circumstances, and expected that for some pulp plant configurations this cost could be as high as $5 million.

No incremental operating or maintenance costs were expected compared with the conventional system. The equipment cost were linearly scaled to match the ISTUM dirty direct heat size categories.

Maximum Market Fraction

The potential market size for this technology was not clearly identified by the proposer. EEA estimated the technology might compete for 1 percent of the dirty direct heat in paper making.

Data Quality

The ISTUM technology specification for this process modification suffers from the early stage of development of this project and the difficulty of modeling a 4 fuel technology. For these reasons, EEA gave the pulp sludge drying technology a "C" data quality code.

Technology name: Direct Reduction of Aluminum
Technology I.D.: 2.46

The direct reduction method of making aluminum is a radical process change, from the conventional Hall cell technology. The new aluminum technology would save 50,000 Btu/lb over conventional electrolytic production.

The technology data supplied by the DOE project manager was based upon a 300,000 ton/year direct heat process that could potentially displace 38×10^{12} Btu/year of electric energy. Although the ISTUM specification is based upon this data, the final technology specification was scaled to one third this size to avoid a technical computer modeling problem associated with the size specification of this technology. The following table compares the two aluminum technologies:

	Direct Reduction	Conventional Electrolytic
Plant size	300,000 tons/year	300,000 tons year
Btus of Fuel consumed	38×10^{12} Btu/year	38×10^{12} Btu/year
Service Sector	Direct Heat*	Electrolytic
Fuel Use Efficiency	.8**	1.0
Hours of Operation	6500	6500
Service Demand	$\frac{(38 \times 10^{12}) \times 8}{6500} =$	$\frac{(48 \times 10^{12}) \times 1.0}{6500} =$
	4676 MMBtu/hr	7384 MMBtu/hr

* Since the direct reduction process is a substitute for the the electrolytic service sector, the technology is actually placed in the electrolytic service sector.

** The DOE project manager states that this efficiency is the result of capturing off gases from the blast furnaces.

Service Demand Displacement

The service demand displacement for the direct reduction process is based upon the service demand of the conventional system. One direct reduction unit is equal to a 7384 MMBtu/hr electrolytic plant. Since this size exceeded ISTUM model limits, EEA scaled this technology specification to one third size or 2462 MMBtu/hr. To reflect the efficiency improvements of this process, the final fuel use efficiency was made 1.58, based upon the ratio of electrolytic service demand to direct reduction service demand.

$$\frac{\text{electrolytic service demand}}{\text{direct reduction service demand}} = \frac{7384}{4676} = 1.58$$

Equipment Cost

The DOE project manager indicated a capital cost of $150 million dollars. Based upon the one third scale down, EEA estimated 20 percent of all direct reduction plants would cost from $50 to 60 million. An additional 60 percent of all facilities would cost from $60 to 100 million.

Operating and maintenance costs were estimated at 12 percent of capital cost. The one third scale direct reduction was linearly sized to the ISTUM 600 MMBtu/hr electrolytic size category.

Maximum Market Fraction

Due to the early development stage of this technology, the maximum market fraction is surrounded by uncertainty. The chemical properties of the new aluminum, might limit the market for direct reduction to aluminum used in casting, about 15 percent of production in 1976.

Data Quality

Due to the difficulties of modeling direct reduction, the lack of outside documentation, and some of the technical uncertainties about the new process, EEA considered the data quality to be code "C".

Technology name: Aluminum Smelter Modification

Technology I.D.: 2.56

The aluminum smelter modification specification in ISTUM is based upon an improved cathode for the basic Hall cell. Although primarily conceived as a retrofit technology, this process modification would also apply to new aluminum facilities. The smelter modification would not be applicable for Direct Reduction of Aluminum (ISTUM technology 2.46).

Service Demand Displacement

With a 25 percent savings of electrical energy over the existing Hall cell process, the service demand displacement in the electrolytic service sector is as follows:

$$\text{fuel efficiency} \times \frac{\text{annual energy consumption} \times \text{fraction saved}}{\text{hours of operation}} = \text{ISTUM Service Demand Displacement}$$

$$1.0 \times \frac{22.75 \times 10^9 \text{ Btu/cell/yr.} \times .25}{6500 \text{ hr/yr.}} = .88 \text{ MMBtu/hr.}$$

Equipment Cost

The DOE project manager estimate a capital cost of $165,000 including a $40,000 installation charge for an ideal application of this technology. EEA assumed that half of all aluminum cells could be modified for a cost (block A 2.56) between $165,000 and $185,000 based upon a 50 percent increase in installation cost. Another 40 percent of all applications would face installation charges between 50 and 100 percent greater than the ideal modification cost.

EEA assumed that the operating and maintenance charge of the new technology would equal the conventional system, so no incremental O&M was reported in the ISTUM specification: The cathode modification cost was linearly scaled up to the ISTUM electrolytic service sector size of 600 MMBtu/hr.

Maximum Market Fraction

This technology is applicable to all existing and new aluminum production facilities based upon the Hall cell. With a 25 percent savings in electrolytic energy, the ISTUM maximum market fraction is 0.25. The current formulation of the ISTUM model logic does not adjust for the presence of a mutually exclusive aluminum technology, direct reduction. Nor does the model provide any information about attractiveness of premature retirement and retrofit applications of the cathode modification.

Data Quality

The cost and energy savings of this technology received a "C" data quality code because no component break down of cost or supporting technical documentation of energy savings was provided by either the proposer or the DOE project manager. The maximum market fraction received a quality "C" code because of the ISTUM model's inability to consider the interaction of the Aluminum Smelter Modification with the Direct Reduction of Aluminum technology.

Technology Name: Lube Oil Recovery
Technology I.D.: 2.57

This DOE sponsored research project is directed at the development of an improved process for recovering lube oil. The ISTUM specification is based upon a 10×10^6 gallon/year re-refining plant. The lube oil recovery technology competes for liquid feedstock service demand in SIC-29 petroleum refining and related industries.

Service Demand Displacement

The DOE project manager indicated that the proposed re-refining plant would process 10×10^6 gallons per year with a 70 percent efficiency. Since the re-refined oil would consume 1.28×10^6 Btu/Bbl compared to 2.2×10^6 Btu/Bbl for virgin lube oil, this technology would save about 21,900 Btu/gallon of lube oil. Based upon this data, the service demand displacement for this technology is:

$$\frac{\text{plant capacity} \times \text{efficiency} \times \text{energy savings}}{\text{hours of operation}} = \text{service demand displacement}$$

$$\frac{10 \times 10^6 \text{ gal/yr} \times .7 \times 21{,}900 \text{ Btu/gal}}{8000 \text{ hours/year}} = 19 \text{ MMBtu/hr.}$$

Equipment Cost

The proposer identified a capital cost of \$3 million for a re-refining facility. EEA assumed this cost represented an ideal application, and that only 50 percent of all lube oil recovery plants would be built at a cost of \$3 to 3.6 million dollars. Another 40 percent of all applications were expected to cost from \$3.6 to 5 million dollars. Operating and maintenance charges were expected to annually total 12 percent of the total installed capital cost. The 19 MMBtu/hr unit was linearly scaled to 250 MMBtu/hr size category in the liquid feedstock service sector.

Maximum Market Fraction

EEA calculated that 25 percent of annual consumption of 1.35×10^9 gallons of lube oil in the United States could be collected from fleet maintenance yards, gasoline stations, and lube oil recycling centers (such as sponsored by states under EPCA). Based upon a 10×10^6 gallon/year facility, the total market for re-refining plants is:

$$\frac{1.35 \times 10^9 \text{ gallon/year} \times .25}{10 \times 10^6 \text{ gallon/year/plant}} = 34 \text{ plants}$$

Using a 34 plant market the maximum service demand displacement is:

$$\text{number of plants} \times \text{hourly service demand} \times \text{hours of operation} = \text{maximum service demand displacement}$$

$$\underset{\text{plants}}{34} \times \underset{\text{Btu/hr}}{19 \times 10^6} \times \underset{\text{hr/yr}}{8000} = \underset{\text{Btu/hr}}{5.168 \times 10^{12}}$$

The maximum market fraction is therefore:

$$\frac{\text{maximum service demand displacement}}{\text{liquid feedstock service demand}} = \text{maximum market fraction}$$

$$\frac{5.168 \times 10^{12}}{736.4 \times 10^{12}} = .007$$

Data Quality

The primary weakness in the data supporting this technology was the energy savings calculation. Because the energy savings was not verified by engineering analysis or by an outside reviewer, EEA gave the lube oil recovery technology a "C" quality code.

Technology Name: Polypropylene to Fuel

Technology I.D.: 2.413

The focus of this proposed DOE project is the thermal cracking of waste atactic polypropylene into a low sulfur #6 fuel oil. The ISTUM technology specification is based upon a 200 million lb/year plant. EEA placed the polypropylene technology in the non-coal indirect heat service sector.

Service Demand Displacement

The 200 million pound per year plant could create 3.46 x 10^{12} Btu/year of #6 fuel oil according to the proposer. The plant would consume 2.4 x 10^{6} KwH/year of electricity. Based upon this data, the service demand displacement would be:

$$\frac{(3.46 \times 10^{12} \text{ Btu/year}) \times .7 - (2.4 \times 10^{6} \text{kWh/yr} \times \frac{3413}{1} \times .9)}{8300 \text{ hr/yr.}} =$$

291 MMBtu/hr

Equipment Cost

The proposer identified a $2 million dollar capital cost for a polypropylene cracking plant. EEA assumed that this represented an ideal application, and that some applications might face a cost 50 percent higher, or $3 million.

The proposer indicated that operating and maintenance would include a $3.5 million cost for atactic polypropylene collection and a $300,000 credit for avoided landfilling costs. This resulted in a net O&M of 2 percent.

Maximum Market Fraction

The calculation of a maximum market fraction for this technology is hindered by significant lack of information. No reliable prediction of future production of atactic polypropylene exists today. In addition, the economics of recovering previously landfilled polypropylene have not been determined. EEA conservatively estimated a market for two 200 x 10^6 lb/year plants in 1978. Based upon a 291 MMBtu/hr service demand displacement and 8300 hr/year operation, the maximum market fraction is:

$$\frac{\text{maximum service demand displacement}}{\text{ISTUM service sector service demand}} = \text{maximum market fraction}$$

$$\frac{2 \times 291 \times 10^6 \times 8300}{286.7 \times 10^{12}} = .0168$$

Data Quality

The use of a very conservative maximum market fraction made a "B" data quality code. However the difficulties of modeling the energy savings of this technology, essentially involving a new product and uncertain costs for waste material, indicated a "C" quality code for energy savings was appropriate.

Technology name: Refuse in Cement Kiln
Technology I.D.: 2.414

Refuse derived fuel (RDF) is a combustible material extracted from municipal solid waste. The goal of this DOE sponsored project is the 30 percent substitution of RDF for conventional fuels in the calcining service sector for SIC 32, the cement industry. Approximately two thirds of all cement is produced in coal fired kilns. Therefore in most plants, implementing this technology would substitute one relatively dirty fuel for another.

Service Demand Displacement

Data from the Portland Cement Association 1/ suggests that new dry-process cement kilns will consume approximately 6×10^6 Btu/ton. The DOE project data assumes an energy savings of 550×10^9 Btu/year for a 305,000 ton/year kiln. The hourly rating for this example is therefore:

Combustion efficiency		Percent RDF substitution		Energy Consumption per ton		capacity		service demand displacement
.33	x	.3	x	6 MMBtu/ton	x	$\frac{305{,}000 \text{ ton/yr}}{7000 \text{ hr/yr}}$	=	25.9 MMBtu/hr

Equipment Cost

The DOE technology documentation reported a $2 million capital cost for a modification of a 305,000 ton/day cement kiln,

1/ Energy Conservation Potential in the Cement Industry, FEA Conservation - Paper 26, June 1975 and 1974 Energy Report for the U.S. Portland Cement Industry: Summary Analysis, Portland Cement Association, May 1975.

but provided no breakdown of the components of the charge. EEA assumed this data was based upon an ideal application and specific circumstances at some plants could increase this cost to $3 million (block 2.414). Operating and maintenance charges were estimated to be 5 percent of capital costs. A linear scaling factor of 1.54 was used to match the ISTUM size category of 40 MMBtu/hr. in the calcining service sector.

Fuel Used

A market price for RDF does not exist in the United States at this time. The handful of demonstration programs in solid waste combustion identified significant technical obstacles in the preparation and combustion of refuse fuels. If these hurdles could be passed and a viable market for RDF created, EEA assumes the fuel price would generally track the price of coal. Since ISTUM does not have an RDF price, the "fuel" for this technology was therefore specified as coal.

Maximum Market Fraction

The potential market for this technology theoretically includes 385 kilns which annually produce 85×10^6 tons of cement. However, many of these kilns are located far from urban areas and a reliable source of refuse fuel. EEA assumed that about half of the U.S. production would face this restriction. The maximum service demand displacement for a 100 percent penetration of the remaining market would be:

U.S. Production		Unit Energy Consumption		Combustion Efficiency		Maximum RDF Substitution		RDF Availability Restriction		maximum service demand displacement
85×10^6 ton/yr	x	6×10^6 Btu/yr	x	.33	x	.3	x	.5	=	25.2×10^{12} Btu/yr.

The ISTUM maximum market fraction is :

$$\frac{\text{maximum technology service demand displacement}}{\text{applicable industry service demand}} = \text{maximum market fraction}$$

$$\frac{25.2 \times 10^{12}}{324.7 \times 10^{12}} = .078$$

Data Quality

The energy savings and potential market for a RDF system could be calculted from the Portland Cement Association data. However, the costs of this technology are based upon poorly documented equipment costs and considerable uncertainty about the market price for RDF. The ISTUM quality codes reflect the reliability of technology specification from this data. Cost is considered "C" quality data, while maximum market fraction and energy savings are rated as "B" quality data.

Technology name: Blended Cement

Technology I.D.: 2.514

The blending of pozzolanic material, such as blast furnace slag or fly ash into Portland cement can reduce the overall energy consumption in cement production. According to Portland Cement Association data[1/], approximately 7 percent of current United States cement production is blended with pozzolanic material. This DOE project aims at increasing the market for blended cement by overcoming existing institutional and technical barriers. The ISTUM technology specification is based upon a 250,000 ton/year cement kiln using a 30 percent substitution of fly ash or slag. The impact of the DOE program supporting this process change in the calcining service sector is expected to have its initial impact in 1980.

Service Demand Displacement

The energy consumption of new cement kilns utilizing the dry process averages about 6×10^6 Btu/year. The service demand displacement for a 250,000 ton/year blended cement plant using a 30 percent substitution of pozzolanic material is:

Hourly Capacity	x	Percent Energy Savings	x	Energy Consumption	x	Fuel Efficiency	=	Service Demand Displacement
$\frac{250{,}000 \text{ ton/yr}}{7000 \text{ hr/yr.}}$	x	.30	x	6×10^6 Btu/ton	x	.33	=	21.2 MMBtu/hr.

Equipment Cost

Based upon the proposer's estimate of $5.00 per ton of capacity for a blended cement facility, the minimum cost (Block A 2.514)

1/ Energy Conservation Potential in the Cement Industry FEA Conservation Paper 26, June 1975.

for a 250,000 ton/year plant is \$1.25 million. EEA assumed that half of all potential applications would fall between this minimum cost and \$1.45 million. Only 10 percent of all cement plants were expected to incur equipment and installation costs greater than \$7.00 per ton of capacity, or \$1.75 million for a 250,000 ton/year facility.

Operating and maintenance charges for blended cement equipment were estimated to be 5 percent of capital costs. The additional electricity costs of this technology were considered minor and are included in the O&M charge.

Maximum Market Fraction

The 385 kilns in the United States currently produce 85 million tons of cement each year. EEA conservatively estimated that overcoming technical hurdles and relaxing institutional barriers could potentialy increase the market from 7 to 50 percent of total production. Based upon a 30 percent substitution of pozzolanic material, the maximum service demand displacement of the technology is:

Energy consumption/ton	x	Percent Savings	x	U.S. Production	x	Fuel Efficiency	x	Technical Limitations	=	Maximum service demand displacement
6×10^6 Btu/ton	x	.30	x	85×10^6 tons/yr.	x	.33	x	.5	=	25.2×10^{12} Btu/year

The ISTUM maximum market fraction is:

$$\frac{\text{maximum service demand displacement}}{\text{industry service sector demand}} = \text{maximum market fraction}$$

$$\frac{25.2 \times 10^{12}}{324.7 \times 10^{12}} = .078$$

Data Quality

The ISTUM specification for blended cement is based on data from the Portland Cement Association, the DOE project manager, and the proposer. The technical data is supported by operating characteristics of blended cement facilities in Japan, Germany, Italy, and the United States. Therefore EEA rated the data quality for all categories in blended cement as "B".

Technology Name: Glass Conglomerate

Technology I.D.: 2.415

The glass conglomerate technology is a method for preheating pelletized glass container batch (with potential applications in other glass processes) to save meeting energy, increase furnace life expectancy, and reduce air pollution. Under some circumstances this technology could significantly increase the capacity of an existing furnace. However, the ISTUM specification is based upon a 150 ton/day glass regenerative furnace operated a 80° C lower temperature. In addition to energy savings, and pollution control a furnace operated in this manner would require less frequent furnace wall rebuilds.

Service Demand Displacement

The service demand displacement calculation is based upon a 150 ton/day furnace operating 7920 hours/year.* The conventional furnace consumes 328×10^{9} Btu/year but the pelletized preheating glass furnace consumes 307×10^{9} Btu/year. Based upon a 21×19^{9} Btu/year fuel savings, the service demand displacement is:

$$\frac{\text{Incremental Fuel Savings} \times \text{Fuel Efficiency}}{\text{hours of operation}} = \text{service demand displacement}$$

$$\frac{21 \times 10^{9} \times .3}{7920} = .795 \text{ MMBtu/hr}$$

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* The proposers documentation is based upon 7920 hour/year operation. The ISTUM assumption for glass melting is 7000 hours/year.

Equipment Cost

The proposer estimated a capital cost of $1 million for this technology. EEA assumed this represented an ideal application and that 50 percent of all applications would cost between $1 and 1.3 million. EEA estimated that another 40 percent of all applications would cost between $1.3 and 1.8 million.

The proposer did not identify the operating costs for this technology. However, operating the furnace at an 80°C lower temperature would extend the wall liner life from 3 to 5 years. The proposer estimated this could annually save $133,000 in maintenance. The glass conglomerate technology might also reduce the need for pollution control equipment. For the ISTUM specification of this technology, EEA assumed a net operating and maintenance savings of 12 percent.

Maximum Market Fraction

The pelletizing preheat technology is currently being tested on a glass container furnace, but could potentially be adapted to flat glass production. The proposer's data indicate an energy savings of slightly higher than 6 percent. Based upon this data, EEA assumed that glass conglomerates could compete for 6 percent of the glass melting market.

Data Quality

The proposer's glass conglomerate documentation emphasizes the tentative nature of the analysis for this technology. Since the glass conglomerate process has not been demonstrated beyond the bench test level, EEA assumed a "C" data quality code was appropriate.

Technology name: Flat Glass Energy Reduction
Technology I.D.: 2.515

The goal of this technology is reducing energy consumption in the flat glass industry. The proposer claimed this could be accomplished by installing optical sensors and microprocessor controls to monitor and control glass output.

Service Demand Displacement

The energy savings potential of this technology has not been technically demonstrated, but may include reducing the cullet percentage in glass melting and optimizing the quantity of glass for a given sheet thickness. If a $.4 \times 10^6$ Btu/ton energy savings can be achieved with this technology, the service demand displacement will be:

$$\text{energy savings} \times \text{combustion efficiency} \times \text{furnace capacity} = \text{service demand displacement}$$

$$.4 \times 10^6 \text{ Btu/ton} \times .3 \times 16.25 \text{ ton/hr} = 1.95 \text{ MMBtu/hr}$$

Equipment Cost

The proposer indicated that an ideal application of this technology would cost about $70,000. EEA assumed that unique circumstances in some glass plants could result in a total installed cost of $140,000. The ISTUM capital cost distribution for this technology (Block A2.515) was based upon this range.

Annual operating and maintenance charges were antipated to be 10 percent of capital costs. The 1.95 MMBtu/hr glass sensing equipment was linearly scaled to both ISTUM glass melting size categories.

Maximum Market Fraction

The proposer indicated a market for this technology in 38 glass plants. The maximum service demand displacement for a plant with this control technology might be calculated as follows:

energy savings	x	technical applicable	x	annual capacity	x	combustion efficiency	=	maximum service demand displacement
0.4×10^6 Btu/ton	x	.75	x	136,500 ton/yr.		.3		12×10^9 Btu/yr

Based upon the proposer's estimate of 38 applications in the United States, the maximum market fraction is:

$$\frac{\text{Service Demand Displacement for Total Market Penetration}}{\text{ISTUM Glass Melting Service Demand}} = \text{Maximum market fraction}$$

$$\frac{38 \times (12 \times 10^9)}{79.4 \times 10^{12}} = .006$$

Data Quality

The DOE project manager indicated that the flat glass energy reduction proposal is still in its early stages of development. The technology data has not been verified by outside review or engineering calculations. Because of the lack of corroborating data and the poor definition of the source for energy savings, EEA considered very low data quality codes appropriate.

Technology name: Cement Block Drying
Technology I.D.: 2.516

The curing of cement block at 150°F currently consumes 3300 to 6000 Btu/block, although ideally the process should consume only 1000 to 1400 Btu/block. This DOE sponsored technology is directed at minimizing energy consumption of this process by adding pozzolanic material to the cement mix, insulating the curing unit, and using the exothermic reaction in the block to drive the curing process. For the ISTUM specification, the modified curing technology was placed in the brick making service sector as a process change.

Service Demand Displacement

Proposal data indicated that cement block kilns using this process could save 1.3×10^9 Btu/year. The ISTUM service demand displacement for this curing modification is therefore:

$$\frac{\text{Annual Energy Savings}}{\text{Hours of operation}} \times \text{fuel efficiency} = \text{service demand displacement}$$

$$\frac{1.3 \times 10^9 \text{ Btu/year}}{2000 \text{ hours/year}} \times .3 = .195 \text{ MMBtu/hr.}$$

For most conservation technologies, the hours of operation used in the service demand displacement calculation is identical to the ISTUM service sector specification. However, in this case EEA determined that the cement block plants typically operate at 2,000 hours/year and not the 7,000 hours/year assumed by ISTUM for the brick firing service sector. Using a load factor of 2000 hour/year therefore increases the accuracy of the service demand displacement calculation in this exceptional case.

Equipment costs

The equipment modifications required for this process change are relatively modest. The cement block curing chambers would be insulated to retain the exothermic heat of the curing reaction. EEA assumed that 90 percent of all cement kilns could adopt this technology at a cost (block A 2.516) of $1750 to $3000. Operating and maintenance costs would be approximately 5 percent of capital cost. The cost of the modified cement block curing process was scaled up linearly to the 13.1 MMBtu/hr brick firing service demand size.

Maximum Market Fraction

EEA estimated that the market for this process change includes approximately 7000 kilns for cement block curing. The maximum service demand displacement for a 100 percent market penetration is:

Existing Market	x	Energy Savings	x	Fuel Efficiency	=	Maximum Service Demand Displacement
7000 units	x	1.3×10^9 Btu/unit/year	x	.3	=	2.73×10^{12} Btu/year

The ISTUM maximum market fraction for cement block curing in the brick firing service sector is:

$$\frac{\text{maximum service demand displacement}}{\text{industry service demand}} = \text{maximum market fraction}$$

$$\frac{2.73 \times 10^{12} \text{ Btu/year}}{80.3 \times 10^{12} \text{ Btu/year}} = .034$$

Data Quality

Because this technology is not technically complex, using conventional insulation practices and proven techniques for modifying the block mix composition, "B" quality codes were appropriate. and modification in the block mix composition, indicated that a "B" quality codes were appropriate.

Technology Name: CUPOLA FURNACE MODIFICATION
Technology I.D.: 2.417

The off-gases of conventional cupola furnaces contains large quantities of carbon monoxide which is typically incinerated by a natural gas after burner. The cupola modifications proposed in this DOE sponsored project would allow a furnace to operate without the natural gas incineration. For the ISTUM model, this technology was placed in the ironmaking service sector.

Service Demand Displacement

The proposer of this technology indicated that a typical cupola furnace modification could save 35 x 10^9 Btu/year of natural gas. Based upon this data, the annual service demand relief is:

$$\frac{\text{energy savings} \times \text{combustion efficiency}}{\text{hours of operation}} = \text{service demand displacement}$$

$$\frac{35 \times 10^9 \times .4}{5000} = 2.8 \text{ MMBtu/hr}$$

Equipment Cost

The proposer indicated a capital cost range of $60,000 to $90,000 for this technology. EEA assumed that 20 percent of all applications would cost between $60,000 and $75,000. Extenuating circumstances in 60 percent of the applications would increase the price to $75,000 to $90,000.

No incremental operating or maintenance costs are anticipated. The 2.8 MMBtu/hr service demand displacement required that the cupola modification capital costs be linearly scaled to ISTUM size categories in ironmaking.

Maximum Market Fraction

The market for this technology includes about 1,000 existing cupolas in the United States. However, the future market for this technology depends upon the economic viability of the cupola iron casting process. EEA calculated a conservative maximum market fraction by assuming only half of existing cupolas would be technically suitable. The maximum market fraction is therefore.

$$\frac{\text{technical limitation} \times \text{total market units} \times \text{energy savings} \times \text{combustion efficiency}}{\text{ISTUM ironmaking service demand}} = \text{maximum market fraction}$$

$$\frac{.5 \times 1000 \times 35 \times 10^{9} \times .4}{46.3 \times 10^{12}} = .15$$

Data Quality

This technology specification was not supported by component cost breakdowns, detailed engineering analysis, or review by outside sources. For these reasons the energy savings and cost data quality were coded as "C". Due to the special difficulties in identifying the potential market for this technology, EEA assumed a "D" quality code for maximum market fraction was appropriate.

Technology Name: Blast Furnace Gasifier
Technology I.D.: 2.219, 2.41

This technology involves the use of existing blast furnaces not currently in operation to produce medium Btu gas (MBG) for industrial applications. There are currently 40 such retired units in the U.S. capable of being retrofitted to consume coal, coke breeze, BOF slag and scrap materials and produce fuel gas, molten iron and slag. In addition to refitting the existing blast furnace to accomodate different proportions of input materials at new charging and residence rates, there is a requirement to add an oxygen plant and the associated piping to support combustion in the furnace.

The specification of this technology is hindered by the following factors:

1. The technology is intended as a retrofit application to utilize existing retired blast furnaces. Because the ISTUM methodology does not currently capture the market dynamics of retrofit technologies, the Blast Furnace Gasifier project must be specified as a new technology.

2. The original specifications for the capital cost of this technology were erroneously assumed not to have included the cost of the oxygen plant and other contingencies. The inclusion of these costs, which were based on the specifications for a similar facility to generate MBG gas, caused the Blast Furnace Gasifier capital cost to nearly double.

3. Little information is available about the MBG gas distribution system required or the cost of such a system. The large volume of gas expected to be produced by the Blast Furnace Gasifier may create a requirement for an extensive pipeline system for its distribution.

The uncertainties associated with the above factors and with the corresponding results of the ISTUM model runs for this technology require that the results not be relied upon as representative of the expected market acceptance of this technology.

Service Demand Displacement

Based on an original estimate for a 20 foot furnace using 630 tons/day of molten metal and 1575 tons/day of coal, the average blast furnace gasifier unit will produce 10 trillion Btu per year of medium Btu gas. Assuming that the Blast Furnace Gasifier is operated for 6000 hours per year (330 days/year) the service demand displacement per unit can be calculated:

$$\frac{\text{annual energy savings}}{\text{hours of operation}} = \text{service demand displacement}$$

$$\frac{10 \times 10^{12} \text{ Btu/yr}}{6000 \text{ hours/yr}} = 1.67 \times 10^{9} \text{ Btu/year}$$

The gasifier operating under these conditions will produce 1.67×10^{9} Btu/year of MBG gas. The unit will consume roughly 20 percent more energy in the coal input than is produced by the process, for an overall efficiencies of approximately 75 percent.

Equipment Cost

As previously indicated the installed capital costs, including contingencies, for this technology were estimated to be nearly twice the cost indicated by the project manager. The original specifications were assumed to exclude the cost of the oxygen plant and other contingencies. The cost of the components erroneously added to account for these factors more than doubles the annualized capital cost of the technology. For more information concerning the specification of these additional components (boiler equipment, site preparation, gas distribution system, etc.), refer to the description of the medium Btu Gasifier technology.

Credits

The Blast Furnace Gasifier technology receives for a producing hot metal in addition to MBG. Assuming that one and one half ton of ore is required to produce 1 ton of hot metal in this process, the net credit for the iron produced is:

VALUE OF IRON PRODUCED (@ $100/TON)
− COST OF ORE REQUIRED (@ $50/TON)

NET CREDIT FOR IRON PRODUCED

$$\frac{\$100/\text{ton}}{\text{iron}} \times 630\ \frac{\text{tons/day}}{\text{iron}} \times 330\ \text{days/yr} = \$20.79 \times 10^6$$

$$-\frac{\$50/\text{ton}}{\text{ore}} \times 630\ \frac{\text{tons/day}}{\text{iron}} \times \frac{1.5\ \text{tons ore}}{\text{ton iron}} \times 330\ \text{days/yr} = \$15.59 \times 10^6$$

NET CREDIT FOR IRON $\$4.2 \times 10^6$

Maximum Market Fraction

The maximum market fraction is determined as the service demand displaced for all units potentially able to use the technology. The service demand for the Blast Furnace Gasifier is determined as the service demand relief provided to the end users of the MBG produced. Hence, the service demand calculation subsumes the efficiency of the end use process into the calculation:

$$40 \text{ plants} \times 10 \times 10^{12} \frac{\text{Btu}}{\text{plant}} \times .75 \text{ end use conversion efficiency} = .3 \times 10^{15} \text{ Btu service demand}$$

Competing in the steam and steel reheat service sectors, this technology is expected to provide only a fraction of the end use energy requirement. It is estimated that from 20 to 25 percent of the energy in these and other sectors can use low or medium Btu gas. There, assuming 240 Btu is available for use in steam production and 60 Btu for steel reheating the maximum market fraction can be estimated for these service sectors:

$$\frac{\text{fraction of low Btu applications} \times \text{steam service demand relief}}{\text{steam service demand requirement}} = \text{steam market fraction}$$

$$\frac{.25 \times 240 \times 10^{12} \text{ Btu}}{192 \times 10^{12} \text{ Btu}} = .31$$

$$\frac{\text{Fraction of low Btu Applications} \times \text{Steel Reheat service demand relief}}{\text{Steel Reheat Service Demand Requirements}} = \text{steel reheat market fraction}$$

$$\frac{.25 \times 60 \times 10^{12} \text{ Btu}}{66 \times 10^{12} \text{ Btu}} = .22$$

Data Quality

The uncertainty associated with the capital costs of this technology has already been acknowledged. Even after the charges for site preparation, feed water, boiler, and gas distribution systems are resolved, the range of capital costs is expected to be very high. Because of these difficulties, the energy savings data was given a "C" quality code.

The extremely large size of the blast furnace gasifier requires a cluster of MBG users. Very little data is available on the potential for linking major industrial energy consumers. Since these concerns are based upon retrofit applications which are not accomodated by the current ISTUM model logic and involve the service demand in multiple service sectors EEA rated the maximum market fraction as "D" quality data in recognition of the modeling difficulties.

The supporting documentation for the fuel switching potential for this technology was relatively good and could be partially confirmed by engineering calculations. EEA rated the energy savings component of the blast furnace gasifier as "B" quality data.

Technology name: Moving Beam Furnace

Technology I.D.: 2.419

The Moving Beam technology involves an improved transportation mechanism in a steel reheating furnace. The new unit reduces the vibration in the furnace, thereby maintaining the integrity of the insulation, a major problem with conventional walking beam or pusher furnaces. The ISTUM specification is based upon data from the American Iron and Steel Institute report Energy Conservation in the Iron and Steel Industry (page 121) for new applications in steel reheating.

Energy Savings

The AISI data claims the moving beam furnace uses 2.25×10^6 Btu/ton compared to a conventional walking beam or pusher furnace which consumes 2.4×10^6 Btu/ton. The ISTUM service demand rating of a 300 ton/hour moving beam furnace is:

capacity	x	incremental energy savings	x	fuel efficiency	=	ISTUM service demand displacement
300 ton/hr	x	$.15 \times 10^6$ Btu/ton	x	.33	=	15 MMBtu/hr.

Equipment Cost

The capital cost of this technology (block A2.419) was drawn from the AISI data. About 20 percent of the applications were expected to cost between $2.0 and $2.6 million dollars. An additional 60 percent of the units were expected to cost between $2.6 and 3.5 million dollars. EEA estimated that operating and maintenance charges for the moving beam technology would be equal to those in the conventional system, so the ISTUM specification includes no incremental O&M costs. Because the moving beam furnace is rated at 15

MMBtu/hr, EEA used linear scaling factors to set capital costs at the ISTUM steel reheating service sector sizes. of 3 and 60 MMBtu/hr.

Maximum Market Fraction

Only 50 percent of all reheating involves steel slabs. The ISTUM maximum market fraction for this technology is as follows:

technical market limit		percent energy savings		maximum market fraction
.5	x	$\frac{.15 \times 10^6 \text{ Btu/ton}}{2.4 \times 10^6 \text{ Btu/ton}}$	=	.03125

Data Quality

Due to the discrepancies between the AISI and DOE project manager data for the moving beam furnace, EEA rated the technology specification as a "C" data quality code. An additional reason for the low data quality code was the potential difficulties of modeling the possible differences in throughput capacity between the monobeam and conventional steel reheating technologies. The transport mechanism in the moving beam may significantly increase the capacity of reheat furnaces, thereby reducing the total number of furnaces required.

GENERAL IDENTIFICATION FOR CONSERVATION TECHNOLOGIES

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TECH ID	TECHNOLOGY NAME	YEAR AVAIL	FUELS USED		FUEL SHARE (1ST FUEL)	FUEL EFFECIENCY COMB USTN	TRAN SMIS	FINL USE	SIZE RANGE (MMBTU/HR) LO	HI	LOAD RANGE (HRS/YR) LO	HI	MAXIMUM FRACTION INCRE MENTL	RETRO FIT	CONSE RVATN
2.11	BOIL AIR/FL CON	1980	7		1.00	1.00	1.00	0.82	¯1	¯1	¯1	¯1	1.00	0.00	0.02
2.113	HTR AIR/FL CON	1980	7		1.00	1.00	1.00	0.67	¯1	¯1	¯1	¯1	1.00	0.00	0.02
2.12	HTR AIR/FL CON	1960	7		1.00	1.00	1.00	0.36	¯1	¯1	¯1	¯1	1.00	0.00	0.02
2.13	HTR AIR/FL CON	1980	7		1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	1.00	0.00	0.02
2.21	HEAT PUMP-STEAM	1982	4	6	¯1.67	3.30	0.98	0.98	0	100	¯1	¯1	0.10	0.00	1.00
2.219	BLAST FURN→MBG	1982	1		1.00	0.75	0.94	0.40	¯1	¯1	¯1	¯1	0.30	0.00	1.00
2.22	COAL ALUM REMEL	1982	1		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.66	0.00	1.00
2.26	GAS TUTB ORB	1980	2		1.00	1.00	1.00	0.46	¯1	¯1	¯1	¯1	1.00	0.00	1.00
2.31	PLTRY PROC MOD	1980	6		1.00	1.00	1.00	0.60	50	50	4000	4000	0.03	0.00	1.00
2.314	HIGH TEMP RECUP	1980	6		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.05	0.00	1.00
2.315	HIGH TEMP RECUP	1980	6		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.13	0.00	1.00
2.317	HIGH TEMP RECUP	1980	6		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.18	0.00	1.00
2.319	HIGH TEMP RECUP	1980	6		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.18	0.00	1.00
2.32	HIGH TEMP RECUP	1980	6		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.18	0.00	1.00
2.33	HIGH TEMP RECUP	1980	6		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.18	0.00	1.00
2.41	BLAST FURN→MBG	1982	1		1.00	0.75	0.94	0.82	¯1	¯1	¯1	¯1	0.20	0.00	1.00
2.413	POLYPROPYL FUEL	1980	7		1.00	1.00	1.00	0.70	¯1	¯1	¯1	¯1	0.01	0.00	1.00
2.414	REFUSE→CMT KILN	1980	1		1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	0.08	0.00	1.00
2.415	GLASS CONGLOM	1982	6		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.06	0.00	1.00
2.417	CUPOLA FURN MOD	1983	7		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.15	0.00	1.00
2.419	MOVING BEAM	1983	7		1.00	1.00	1.00	0.33	¯1	¯1	¯1	¯1	0.03	0.00	1.00
2.43	PAPER PULP SLDG	1982	4	2	2.15	1.00	1.00	1.54	¯1	¯1	¯1	¯1	0.01	0.00	1.00
2.46	DIRECT RED ALUM	1985	1		1.00	1.00	1.00	1.26	¯1	¯1	¯1	¯1	0.15	0.00	1.00
2.51	HDBX FOR PAPER	1982	7		1.00	1.00	1.00	0.82	250	250	7000	7000	0.03	0.00	1.00
2.514	BLENDED CEMENT	1980	5		1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	0.07	0.00	1.00
2.515	FLAT GLASS EN R	1982	7		1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	0.01	0.00	1.00
2.516	CEM BLOCK DRYG	1979	5		1.00	1.00	1.00	0.30	¯1	¯1	¯1	¯1	0.03	0.00	1.00
2.56	ALUM SMLTER MOD	1981	6		1.00	1.00	1.00	1.00	¯1	¯1	¯1	¯1	0.12	0.00	1.00
2.57	LUBE OIL REC	1981	5		1.00	1.00	1.00	0.70	¯1	¯1	¯1	¯1	0.01	0.00	1.00
2.61	PULP PAPER CHAR	1984	7		1.00	1.00	1.00	0.82	¯1	¯1	¯1	¯1	0.02	0.00	1.00
2.71	HYPERFILTRATION	1980	6		1.00	1.00	1.00	0.82	¯1	¯1	¯1	¯1	0.24	0.00	1.00
2.81	LOW LEVL HT PMP	1982	4	6	0.33	2.50	0.98	0.98	0	200	¯1	¯1	0.05	0.00	1.00
2.91	FOAM FIBER TECH	1979	7		1.00	1.00	1.00	0.82	¯1	¯1	¯1	¯1	0.15	0.00	1.00
2.92	HT PMP-BRAYTON	1982	4	6	¯1.55	2.50	0.98	0.98	¯1	¯1	¯1	¯1	0.05	0.00	1.00

GENERAL IDENTIFICATION FOR CONSERVATION TECHNOLOGIES continued

TECH ID	TECHNOLOGY NAME	SERV SECT	DATA QUALITY MAX FRAC	COST	ENER SAVE	ACCE LER	CONST PER (YRS)	PHYS LIFE (YRS)	DOE ACCEL (YRS)	LAST UPDATED
2.11	BOIL AIR/FL CON	1	B	B	B	C	0.1	20	4	MAR 13, 1978 3:02:37 PM
2.113	HTR AIR/FL CON	13	B	B	C	C	0.1	20	4	MAR 20, 1978 9:42:28 PM
2.12	HTR AIR/FL CON	2	B	B	C	C	0.1	20	4	MAR 17, 1978 9:46:03 PM
2.13	HTR AIR/FL CON	3	B	B	C	C	0.1	20	4	MAR 17, 1978 9:46:50 PM
2.21	HEAT PUMP-STEAM	1	D	B	B	C	1.0	15	3	APR 6, 1978 9:10:11 AM
2.219	BLAST FURN+MBG	19	D	C	B	C	2.0	20	3	MAR 17, 1978 9:37:11 PM
2.22	COAL ALUM REMEL	2	D	C	C	C	2.0	30	5	MAR 17, 1978 9:36:05 PM
2.26	GAS TUTB ORB	6	B	B		C	1.0	20	2	MAR 17, 1978 10:42:54 PM
2.31	PLTRY PROC MOD	1	C	B	B	C	0.1	10	5	APR 5, 1978 5:30:53 PM
2.314	HIGH TEMP RECUP	14	B	B	B	C	1.0	10	1	MAR 15, 1978 1:48:26 PM
2.315	HIGH TEMP RECUP	15	B	B	B	C	1.0	10	1	MAR 15, 1978 1:48:37 PM
2.317	HIGH TEMP RECUP	17	B	B	A	C	1.0	10	1	MAR 15, 1978 1:39:14 PM
2.319	HIGH TEMP RECUP	19	B	B	A	C	1.0	10	1	MAR 15, 1978 1:40:56 PM
2.32	HIGH TEMP RECUP	2	B	B	A	C	1.0	10	1	MAR 28, 1978 11:20:18 AM
2.33	HIGH TEMP RECUP	3	B	B	A	C	1.0	10	1	MAR 15, 1978 1:38:12 PM
2.41	BLAST FURN+MBG	1	D	C	B	C	2.0	20	3	MAR 17, 1978 9:34:12 PM
2.413	POLYPROPYL FUEL	4	B	B	C	C	1.0	20	3	MAR 23, 1978 10:41:53 AM
2.414	REFUSE+CMT KILN	14	B	C	B	C	1.0	20	3	APR 6, 1978 9:12:40 AM
2.415	GLASS CONGLOM	15	C	C	C	C	1.0	20	3	MAR 12, 1978 3:08:24 PM
2.417	CUPOLA FURN MOD	17	D	C	C	C	1.0	30	5	MAR 15, 1978 5:18:28 PM
2.419	MOVING BEAM	19	C	C	C	C	1.0	30	3	MAR 15, 1978 5:17:42 PM
2.43	PAPER PULP SLDG	3	C	C	C	C	1.0	16	3	MAR 27, 1978 4:37:12 PM
2.46	DIRECT RED ALUM	6	C	C	C	C	3.0	40	10	APR 6, 1978 9:12:07 AM
2.51	HDBX FOR PAPER	1	B	C	C	C	0.2	20	5	APR 5, 1978 5:31:00 PM
2.514	BLENDED CEMENT	14	B	B	B	C	1.0	20	5	APR 5, 1978 5:28:59 PM
2.515	FLAT GLASS EN R	15	C	C	D	C	0.2	20	5	MAR 12, 1978 3:00:49 PM
2.516	CEM BLOCK DRYG	16	B	B	B	C	0.2	10	3	MAR 12, 1978 3:02:46 PM
2.56	ALUM SMLTER MOD	6	C	C	C	C	1.0	8	3	MAR 17, 1978 9:43:14 PM
2.57	LUBE OIL REC	7	B	B	C	C	1.0	20	3	MAR 12, 1978 3:14:03 PM
2.61	PULP PAPER CHAR	1	C	C	D	C	0.1	10	10	APR 5, 1978 5:29:10 PM
2.71	HYPERFILTRATION	1	D	C	B	C	1.0	8	3	MAR 13, 1978 3:01:47 PM
2.81	LOW LEVL HT PMP	1	D	B	C	C	1.0	15	3	APR 6, 1978 9:14:29 AM
2.91	FOAM FIBER TECH	1	C	C	C	C	0.1	15	3	APR 5, 1978 5:29:21 PM
2.92	HT PMP-BRAYTON	2	D	B	C	C	1.0	15	3	APR 6, 1978 9:10:57 AM

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TECH ID	TECHNOLOGY NAME	APPLICABLE INDUSTRIES (MODIFIED SIC CODES)																									
		20	21	22	23	24	25	26	27	28	29	30	31	32	331	3334	334	34	35	36	37	38	39	01	02	10	14
2.11	BOIL AIR/FL CON	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2.113	HTR AIR/FL CON	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2.12	HTR AIR/FL CON	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2.13	HTR AIR/FL CON	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2.21	HEAT PUMP-STEAM	1		1		1		1		1		1						1	1	1	1						
2.219	BLAST FURN→MBG														1												
2.22	COAL ALUM REMEL															1											
2.26	GAS TUTB ORB									1					1	1	1										
2.31	PLTRY PROC MOD	1																									
2.314	HIGH TEMP RECUP													1													
2.315	HIGH TEMP RECUP													1													
2.317	HIGH TEMP RECUP														1												
2.319	HIGH TEMP RECUP														1												
2.32	HIGH TEMP RECUP														1	1	1	1									
2.33	HIGH TEMP RECUP														1	1	1										
2.41	BLAST FURN→MBG														1												
2.413	POLYPROPYL FUEL									1																	
2.414	REFUSE→CMT KILN													1													
2.415	GLASS CONGLOM													1													
2.417	CUPOLA FURN MOD														1												
2.419	MOVING BEAM														1												
2.43	PAPER PULP SLDG							1																			
2.46	DIRECT RED ALUM															1											
2.51	HDBX FOR PAPER							1																			
2.514	BLENDED CEMENT													1													
2.515	FLAT GLASS EN R													1													
2.516	CEM BLOCK DRYG													1													
2.56	ALUM SMLTER MOD															1											
2.57	LUBE OIL REC										1																
2.61	PULP PAPER CHAR							1																			
2.71	HYPERFILTRATION			1																							
2.81	LOW LEVL HT PMP	1						1		1	1																
2.91	FOAM FIBER TECH			1																							
2.92	HT PMP-BRAYTON	1																									

CONSERVATION TECHNOLOGY SPECIFICATIONS

BUILDING BLOCK COEFFICIENTS
PRINTED APR 7, 1978 6:35:55 PM

TECH ID 2.11
UPDATED APR 6, 1978 6:13:19 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.11	1.00	15.20	76.20
H 8.11	0.90	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.113
UPDATED APR 6, 1978 9:00:2

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 2.12	1.00	76.20
H 8.11	0.90	1.00
I 8.11	1.00	1.00

TECH ID 2.12
UPDATED APR 6, 1978 9:00:23 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.12	1.00	3.00	15.20
H 8.11	0.90	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.13
UPDATED APR 6, 1978 9:00:23 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.12	1.00	3.00	15.20
H 8.11	0.90	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.21
UPDATED MAR 20, 1978 8:50:58 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.21	1.00	5.00	25.00
H 8.11	0.95	1.00	1.00
I 8.11	1.00	1.00	1.00

CONSERVATION TECHNOLOGIES SPECIFICATIONS continued

TECH ID 2.219
UPDATED APR 7, 1978 11:11:33 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.41	1.00	0.00	0.04
A 8.319	1.00	0.00	1.00
F 8.319	1.00	1.00	0.00
C 8.216	1.00	0.35	3.53
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
E 1.31	1.00	0.08	1.50

TECH ID 2.22
UPDATED MAR 20, 1978 9:11:58 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.22	1.00	0.50	2.30
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.26
UPDATED APR 4, 1978 2:23:4

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 2.25	1.00	6.00
C 5.71	2.40	1.00
H 8.11	0.90	1.00
I 8.11	1.00	1.00

TECH ID 2.31
UPDATED APR 5, 1978 5:19:29 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.31	1.00	6.25	31.25
H 8.11	0.90	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.314
UPDATED MAR 20, 1978 8:50:

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 2.314	1.00	26.70
H 8.11	0.95	1.00
I 8.11	1.00	1.00

CONSERVATION TECHNOLOGY SPECIFICATIONS

TECH ID 2.315
UPDATED MAR 20, 1978 8:50:58 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.315	1.00	27.70	44.50
H 8.11	0.95	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.317
UPDATED MAR 20, 1978 8:50:58 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.317	1.00	1.00	88.70
H 8.11	0.95	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.319
UPDATED MAR 20, 1978 8:50:58 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.319	1.00	2.00	40.00
H 8.11	0.95	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.32
UPDATED APR 7, 1978 11:56:24 AM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.32	1.00	6.70	33.30
H 8.11	0.95	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.33
UPDATED MAR 20, 1978 8:50:58 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.33	1.00	6.70	33.30
H 8.11	0.95	1.00	1.00
I 8.11	1.00	1.00	1.00

CONSERVATION TECHNOLOGY SPECIFICATIONS

TECH ID 2.41
UPDATED MAR 22, 1978 2:44:33 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.41	1.00	0.03	0.15
A 8.11	0.46	0.64	2.10
B 8.11	0.29	0.64	2.30
E 8.11	0.60	0.64	2.25
H 8.11	1.00	1.00	1.00
I 8.11	1.00	1.00	1.00
E 1.31	1.00	1.20	6.00

TECH ID 2.413
UPDATED MAR 22, 1978 2:52:

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 2.413	1.00	0.86
H 8.11	1.00	1.00
I 8.11	1.00	1.00

TECH ID 2.414
UPDATED APR 5, 1978 5:23:3

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 2.414	1.00	1.54
H 8.11	0.95	1.00
I 8.11	1.00	1.00

TECH ID 2.415
UPDATED MAR 20, 1978 9:08:14 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.415	1.00	52.00	83.40
H 8.11	0.95	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.417
UPDATED APR 5, 1978 5:23:33 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.417	1.00	0.57	47.50
H 8.11	0.95	1.00	1.00
I 8.11	1.00	1.00	1.00

CONSERVATION TECHNOLOGY SPECIFICATIONS

TECH ID 2.419
UPDATED MAR 22, 1978 2:48:58 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.419	1.00	0.20	4.00
H 8.11	0.95	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.43
UPDATED MAR 27, 1978 4:24:45 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.43	1.00	0.50	2.50
H 8.11	0.95	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.46
UPDATED APR 5, 1978 5:19:2

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 2.46	1.00	0.24
H 8.11	1.00	1.00
I 8.11	1.00	1.00

TECH ID 2.51
UPDATED APR 5, 1978 5:19:29 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.51	1.00	4.27	21.37
H 8.11	0.95	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.514
UPDATED APR 5, 1978 5:23:3

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 2.514	1.00	1.89
H 8.11	0.95	1.00
I 8.11	1.00	1.00

TECH ID 2.515
UPDATED MAR 22, 1978 2:54:11 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.515	1.00	21.30	34.20
H 8.11	0.90	1.00	1.00
I 8.11	1.00	1.00	1.00

CONSERVATION TECHNOLOGY SPECIFICATIONS

TECH ID 2.516
UPDATED MAR 22, 1978 2:54:

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 2.516	1.00	65.50
H 8.11	0.90	1.00
I 8.11	1.00	1.00

TECH ID 2.56
UPDATED APR 6, 1978 5:25:0

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 2.56	1.00	681.00
H 8.11	0.95	1.00
I 8.11	1.00	1.00

TECH ID 2.57
UPDATED MAR 20, 1978 9:11:

BLOCK ID	BLOCK COEFF	SIZE COEFF
A 2.57	1.00	13.20
H 8.11	1.00	1.00
I 8.11	1.00	1.00

TECH ID 2.61
UPDATED APR 5, 1978 5:19:29 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.61	1.00	7.85	39.25
H 8.11	0.90	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.71
UPDATED MAR 20, 1978 9:07:12 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.71	1.00	42.00	208.00
H 8.11	0.95	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.81
UPDATED APR 5, 1978 5:19:29 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.81	1.00	2.16	10.77
H 8.11	0.95	1.00	1.00
I 8.11	1.00	1.00	1.00

CONSERVATION TECHNOLOGY SPECIFICATIONS

TECH ID 2.91
UPDATED MAR 20, 1978 9:07:12 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.91	1.00	17.00	86.00
H 8.11	0.95	1.00	1.00
I 8.11	1.00	1.00	1.00

TECH ID 2.92
UPDATED MAR 22, 1978 2:56:49 PM

BLOCK ID	BLOCK COEFF	SIZE COEFF	SIZE COEFF
A 2.92	1.00	0.76	3.80
H 8.11	0.90	1.00	1.00
I 8.11	1.00	1.00	1.00

CONSERVATION BUILDING BLOCKS

BUILDING BLOCKS
PRINTED APR 7, 1978 6:40:52 PM

ID: A 2.11
NAME: BOILER AIR FUEL CONTROL
LAST UPDATED APR 6, 1978 9:04:42 AM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 3.28
TYPE S
FRACTION OF COSTS FOR O+M: 0.04
FREQUENCY AND COST DATA:

0.500	115.000
0.400	135.000
0.100	180.000
0.000	0.000

ID: A 2.12
NAME: HTR AIR FL CON
LAST UPDATED APR 6, 1978 9:04:36 AM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 3.28
TYPE S
FRACTION OF COSTS FOR O+M: 0.044
FREQUENCY AND COST DATA:

0.500	115.000
0.400	135.000
0.100	180.000
0.000	0.000

ID: A 2.21
NAME: W4EST HT PMP
LAST UPDATED MAR 15, 1978 5:11:08 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 10
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.500	350.000
0.400	450.000
0.100	600.000
0.000	0.000

ID: A 2.22
NAME: COAL ALUM REMELT
LAST UPDATED APR 5, 1978 8:31:05 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 20
TYPE S
FRACTION OF COSTS FOR O+M: 0.02
FREQUENCY AND COST DATA:

0.500	10,000.000
0.400	11,600.000
0.100	13,800.000
0.000	0.000

CONSERVATION BUILDING BLOCKS

ID: A 2.25
NAME: CAPITAL EQUIPMENT
LAST UPDATED MAR 17, 1978 7:45:33 AM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 100
TYPE 5
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

1.000	7,804.800
0.000	0.000
0.000	0.000
0.000	0.000

ID: A 2.31
NAME: POULTRY PROCEWSS MODIFICation
LAST UPDATED APR 5, 1978 8:29:28 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 8
TYPE 5
FRACTION OF COSTS FOR O+M: 0.04883
FREQUENCY AND COST DATA:

0.300	80.000
0.500	87.000
0.200	94.000
0.000	0.000

ID: A 2.314
NAME: HT REC
LAST UPDATED MAR 15, 1978 5:07:23 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 1.5
TYPE 5
FRACTION OF COSTS FOR O+M: 0.064
FREQUENCY AND COST DATA:

0.500	62.200
0.400	114.400
0.100	167.000
0.000	0.000

ID: A 2.315
NAME: HT REC
LAST UPDATED MAR 15, 1978 5:07:56 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 1.5
TYPE 5
FRACTION OF COSTS FOR O+M: 0.064
FREQUENCY AND COST DATA:

0.500	62.200
0.400	114.400
0.100	167.000
0.000	0.000

CONSERVATION BUILDING BLOCKS

ID: A 2.317
NAME: HT REC
LAST UPDATED MAR 15, 1978 5:09:07 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 1.5
TYPE 5
FRACTION OF COSTS FOR O+M: 0.064
FREQUENCY AND COST DATA:

0.500	62.200
0.400	114.400
0.100	167.000
0.000	0.000

ID: A 2.319
NAME: HT REC
LAST UPDATED MAR 15, 1978 5:10:27 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 1.5
TYPE 5
FRACTION OF COSTS FOR O+M: 0.064
FREQUENCY AND COST DATA:

0.500	62.200
0.400	114.400
0.100	167.000
0.000	0.000

ID: A 2.32
NAME: HT REC
LAST UPDATED MAR 15, 1978 5:06:13 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 1.5
TYPE 5
FRACTION OF COSTS FOR O+M: 0.064
FREQUENCY AND COST DATA:

0.500	62.200
0.400	114.400
0.100	167.000
0.000	0.000

ID: A 2.33
NAME: HT REC
LAST UPDATED MAR 15, 1978 5:06:48 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 1.5
TYPE 5
FRACTION OF COSTS FOR O+M: 0.064
FREQUENCY AND COST DATA:

0.500	62.200
0.400	114.400
0.100	167.000
0.000	0.000

CONSERVATION BUILDING BLOCKS

ID: A 2.41
NAME: BLST FURN GAS
LAST UPDATED MAR 17, 1978 10:06:46 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 1670
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.200	32,000.000
0.600	36,000.000
0.200	42,000.000
0.000	0.000

ID: A 2.413
NAME: POLYPROPYLENE WASTE TO FUEL
LAST UPDATED MAR 22, 1978 2:05:07 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 290
TYPE S
FRACTION OF COSTS FOR O+M: 0.02
FREQUENCY AND COST DATA:

0.500	2,000.000
0.400	2,400.000
0.100	3,000.000
0.000	0.000

ID: A 2.414
NAME: RDF IN CEMENT
LAST UPDATED APR 5, 1978 8:29:34 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 25.9
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

0.500	2,000.000
0.400	2,500.000
0.100	3,000.000
0.000	0.000

ID: A 2.415
NAME: GLASS CONGLOMERATES
LAST UPDATED MAR 27, 1978 4:22:00 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 0.8
TYPE S
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.500	1,000.000
0.400	1,300.000
0.100	1,800.000
0.000	0.000

ID: A 2.417
NAME: CUPOLA FURNACE MODIFICATION
LAST UPDATED APR 5, 1978 8:25:00 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 2.8
TYPE 5
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.200	60.000
0.600	75.000
0.200	90.000
0.000	0.000

ID: A 2.419
NAME: MOVING BEAM SLAB TRANS MECH
LAST UPDATED MAR 15, 1978 5:27:28 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 15
TYPE 5
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.200	2,000.000
0.600	2,600.000
0.200	3,500.000
0.000	0.000

ID: A 2.43
NAME: PAPER PULP SLUDGE DRYING
LAST UPDATED APR 5, 1978 8:31:00 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 15
TYPE 5
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.500	3,000.000
0.400	4,000.000
0.100	5,000.000
0.000	0.000

ID: A 2.46
NAME: DIR RED ALUM
LAST UPDATED APR 5, 1978 8:32:55 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 2466
TYPE 5
FRACTION OF COSTS FOR O+M: 0.12
FREQUENCY AND COST DATA:

0.200	50,000.000
0.600	60,000.000
0.200	100,000.000
0.000	0.000

ID: A 2.51
NAME: HEADBOX FOR PAPER
LAST UPDATED APR 5, 1978 8:30:09 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 11.7
TYPE 5
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.500	700.000
0.400	900.000
0.100	1,200.000
0.000	0.000

ID: A 2.514
NAME: BLENDED CMEENT
LAST UPDATED APR 5, 1978 8:29:39 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 21.2
TYPE 5
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

0.500	1,250.000
0.400	1,450.000
0.100	1,750.000
0.000	0.000

ID: A 2.515
NAME: FLAT GLASS ENERGY REDUCTION
LAST UPDATED MAR 13, 1978 4:01:22 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 1.95
TYPE 5
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.200	70.000
0.500	100.000
0.300	140.000
0.000	0.000

ID: A 2.516
NAME: CEMENT BLOCK CURING
LAST UPDATED MAR 13, 1978 4:10:31 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 0.2
TYPE 5
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

0.500	1.700
0.400	2.000
0.100	3.000
0.000	0.000

ID: A 2.56

NAME: ALUM SMELT MOD

LAST UPDATED APR 5, 1978 8:29:45 PM

SIZE OF UNIT COSTED OUT (MMBTU/HR): 0.88

TYPE 5

FRACTION OF COSTS FOR O+M: 0

FREQUENCY AND COST DATA:

0.500	165.000
0.400	185.000
0.100	205.000
0.000	0.000

ID: A 2.57

NAME: LUBE OIL RECOVERY

LAST UPDATED MAR 13, 1978 4:13:39 PM

SIZE OF UNIT COSTED OUT (MMBTU/HR): 19

TYPE 5

FRACTION OF COSTS FOR O+M: 0.12

FREQUENCY AND COST DATA:

0.500	3,000.000
0.400	3,600.000
0.100	5,000.000
0.000	0.000

ID: A 2.61

NAME: PULP PAPER CHARACTERIZATION

LAST UPDATED APR 5, 1978 8:29:57 PM

SIZE OF UNIT COSTED OUT (MMBTU/HR): 6.37

TYPE 5

FRACTION OF COSTS FOR O+M: 0.05

FREQUENCY AND COST DATA:

0.500	110.000
0.400	120.000
0.100	160.000
0.000	0.000

ID: A 2.71

NAME: HYPERFILTRATION

LAST UPDATED APR 5, 1978 8:30:03 PM

SIZE OF UNIT COSTED OUT (MMBTU/HR): 1.5

TYPE 5

FRACTION OF COSTS FOR O+M: 0.12

FREQUENCY AND COST DATA:

0.500	133.000
0.400	150.000
0.100	180.000
0.000	0.000

CONSERVATION BUILDING BLOCKS

ID: A 2.81
NAME: LLHR HEAT PUMP(MTI)
LAST UPDATED APR 5, 1978 8:29:50 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 23.2
TYPE S
FRACTION OF COSTS FOR O+M: 0.07
FREQUENCY AND COST DATA:

0.500	750.000
0.400	950.000
0.100	1,300.000
0.000	0.000

ID: A 2.91
NAME: FOAM FIBER TECH
LAST UPDATED MAR 13, 1978 4:08:48 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 2.91
TYPE S
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.500	65.000
0.400	85.000
0.100	100.000
0.000	0.000

ID: A 2.92
NAME: HEAT PUMP GARRETT BRAYTON
LAST UPDATED MAR 15, 1978 5:11:54 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 13.2
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

0.500	225.000
0.400	300.000
0.100	500.000
0.000	0.000

ID: A 8.11
NAME: SITE PREP
LAST UPDATED MAR 12, 1978 6:30:33 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.03
FREQUENCY AND COST DATA:

0.500	541.000
0.400	823.000
0.100	1,761.000
0.000	0.000

CONSERVATION BUILDING BLOCKS

ID: A 8.319
NAME: PRIMARY SYSTEM (SMALL SIZE CLASS)
LAST UPDATED MAR 21, 1978 10:02:01 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 3
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.400	50.000
0.400	71.000
0.200	114.000
0.000	0.000

ID: B 8.11
NAME: BOILER EQUIPMENT (GENERAL)
LAST UPDATED MAR 12, 1978 6:54:53 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.115
FREQUENCY AND COST DATA:

0.350	1,500.000
0.550	2,100.000
0.100	2,520.000
0.000	0.000

ID: C 5.71
NAME: DEMAND CHARGE
LAST UPDATED APR 7, 1978 3:53:57 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 250
TYPE L
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.030	1.500
0.940	3.580
0.030	5.670
0.000	0.000

ID: C 8.216
NAME: FUEL HANDLING (OIL)
LAST UPDATED MAR 18, 1978 6:15:06 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 13.1
TYPE S
FRACTION OF COSTS FOR O+M: 0.05
FREQUENCY AND COST DATA:

0.500	77.000
0.500	92.000
0.000	0.000
0.000	0.000

ID: E 1.31
NAME: DISTRIBUTION SUSTEM
LAST UPDATED APR 6, 1978 2:44:40 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 50
TYPE S
FRACTION OF COSTS FOR O+M: 0.08
FREQUENCY AND COST DATA:

0.300	582.000
0.400	930.000
0.300	1,332.000
0.000	0.000

ID: E 8.11
NAME: FEEDWATER SYSTEM AND UTILITIES
LAST UPDATED MAR 12, 1978 7:01:07 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 120
TYPE S
FRACTION OF COSTS FOR O+M: 0.07
FREQUENCY AND COST DATA:

0.200	210.000
0.500	260.000
0.300	660.000
0.000	0.000

ID: F 8.319
NAME: PRIM SYS LARGE SIZE
LAST UPDATED MAR 22, 1978 7:49:25 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 60
TYPE S
FRACTION OF COSTS FOR O+M: 0.1
FREQUENCY AND COST DATA:

0.400	1,000.000
0.400	1,250.000
0.200	1,750.000
0.000	0.000

ID: H 8.11
NAME: INDIRECT CAPITAL COSTS (ENGIN, CONTIN)
LAST UPDATED MAR 12, 1978 7:08:23 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR): 0
TYPE M
FRACTION OF COSTS FOR O+M: 0
FREQUENCY AND COST DATA:

0.550	1.300
0.350	1.400
0.100	1.500
0.000	1.650

```
ID:   I B.11
NAME:  CONSTRUCTION INDICES
LAST UPDATED MAR 12, 1978  7:09:36 PM
SIZE OF UNIT COSTED OUT (MMBTU/HR):  0
TYPE M
FRACTION OF COSTS FOR O+M:  0
FREQUENCY AND COST DATA:
   0.400          0.870
   0.400          0.970
   0.200          1.070
   0.000          1.250

PROGRAM EXITED
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*U.S. GOVERNMENT PRINTING OFFICE : 1979 O-310-912/146