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MASTER

PREPARATION OF A COST DATA BANK FOR
DOE/BIOMASS ENERGY SYSTEMS BRANCH

DOE/ET/20605--T2

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ABSTRACT

This study deals with the preparation of a biomass conversion technology and cost data bank for the Biomass Energy Systems Branch (BES) of DOE/SOLAR. When completed, it may be used with an appropriate methodology to analyze the complex issues of research program planning and analysis. In addition, future market penetration of BES products may be projected, and the options available to the Federal Government to influence the outcome of BES products marketing may also be examined.

Technical and economic analyses of a number of BES technology options are currently underway. A total of 19 biomass conversion technology options (11 thermochemical and 8 biochemical) have been selected for inclusion in the data bank. These options cover the production of electric power, steam, gases, liquids, and solid fuels from biomass. The majority of the options are believed to be available now or in the near-term. A consistent methodology for construction of the data bank has been developed. For each option, the most up-to-date process/product data are gathered and analyzed. A base case is established to generate estimates for plant investments required, operating cost, and product cost. The estimates are then examined systematically to identify and quantify the uncertainties. The uncertainties are combined using statistical methods to produce error band estimates.

An initial scanning of the technology options revealed that the major factors contributing to cost uncertainties for BES products are quite diverse in nature. For processes in early developmental stages, process know-how in terms of conversion, product yields, and thermal efficiency is a major factor. For many biochemical conversion options the by-product(s) (co-product) value(s) will strongly influence the fuel product cost. For a well established technology such as power and steam generation, feed and equipment costs constitute the major uncertainties.

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I INTRODUCTION

An issue central to the conduct of planning and analysis activities for the Solar Energy Division of the Department of Energy (DOE/SOLAR) is the allocation of research and development (R&D) budgets to competing or complementary functions or technologies. The issue is complex. Its investigation generally involves:

- The development of an appropriate and understandable methodology capable of handling the principal variables of the analysis (for example, end-use demand, foreign oil prices, technology economic data, and technology improvements or innovations over time).
- The development of a consistent and acceptable data base for use with the methodology. When the data base has been created and has been reviewed by the appropriate individuals (within DOE, outside of DOE, or both), it may be used with the methodology to analyze the complex issues of program planning and analysis.

This study deals with the preparation of a biomass conversion technology and cost data bank for the Biomass Energy Systems Branch (BES) of DOE/SOLAR. Using the data bank, future market penetration of BES products may be projected. The options available to the Federal Government to influence the outcome of BES products marketing will also be examine.

II OBJECTIVES

The objectives of this study are to:

- Develop a technology and cost data bank for a broad spectrum of advanced thermochemical and biochemical conversion technology options.
- Estimate the likely regional prices, availability and market share of biomass energy products (in quadrillions of Btu per year) using analytical market penetration models.
- Develop a set of cost goals for BES technologies and examine the aids and impediments to achieving these cost goals. Particular emphasis will be placed on the Federal role and available options.

- Conduct a pre-designed sensitivity study on the national market penetration of BES technologies based on interfuel competition analyses and projected end-use energy demands.

III PROJECT SCOPE

The scope of this study encompasses technical and commercialization analyses of BES technologies, an analysis of the Federal Role, and an interfuel competition analysis.

Technical Analysis

A broad based technology and cost data bank will be developed for 19 advanced thermochemical and biochemical biomass energy systems options. Particular emphasis will be placed on identifying:

- Currently available technology, technologies anticipated to be available by 1985, and technologies anticipated to be available in the post-1985 time period.
- The basis for the cost estimates.
- The uncertainties in the cost estimates, quantified as precision limits.
- A consistent format for uniform presentation of results.

Commercialization Analysis

Estimates of regional prices and available quantities of biomass energy products will be developed for the selected BES technology options for the years 1985 to 2020. Learning curve effects for these options will be studied in depth and integrated with regional biomass resource availability and the cost data bank to generate estimates of probable regional market penetration of biomass energy products as a function of such variables as:

- Prices and quantities of non-biomass alternatives.
- End-use demand levels.
- Unfavorable imported energy prices.

An existing market penetration computer model will be used for this analysis.

Analysis of Federal Role

Based on the Technical and Commercialization Analyses results, reasonable cost goals for BES technologies will be developed in coordination with DOE/BES staff. The projected costs and available dates for BES technology options will be the prime factors for consideration in setting the cost goals. Aids and impediments to achieving these cost goals will be enumerated and examined, with particular emphasis on the current and future Federal roles regarding the resolution of the impediments. Where possible, quantitative estimates will be made of BES product cost reductions which could be realized by exercising such Federal options as RD&D expenditures, policy and regulation modifications, tax incentives, and other forms of aids to BES commercialization ventures.

Interfuel Competition Analysis

An estimate of the national market penetration projection for BES fuel products and electricity will be developed, based on their market competitiveness with non-biomass sources. Sensitivity studies on the probable market penetration will be conducted to illustrate the effects of the following variables:

- Foreign oil prices.
- End-use energy demand levels.
- Nuclear power availability.
- Electricity from coal-fired power plants.
- High or low prices of synthetic fuels from coal.
- High or low prices of synthetic fuels from biomass.
- The effect of any of the above on end-use consumer expenditures for energy (consumers' surplus).

The existing SRI National Energy Model, the primary tool for the Interfuel Competition Analysis, will be updated and expanded to incorporate the BES technology options selected for this study.

Program

This study will be conducted in five phases:

- Phase I - Technical Analysis
- Phase II - Workshop for Technical Analysis
- Phase III - Analysis of Technology Commercialization
 - Task 1 - Commercialization Analysis
 - Task 2 - Analysis of Federal Role
- Phase IV - Workshop for Analysis of Technology Commercialization
- Phase V - Interfuel Competition Analysis

The analyses work will be carried out in three phases (I, III, and V). Two workshops (phases II and IV) will be conducted to obtain reviews, inputs, and feedback on the cost data base and analyses conclusions generated by this study. These workshops will assemble members of the government and private sector communities having interest in and expertise in biomass energy systems technologies. The expressed opinions of the participants will be published in workshop proceedings.

IV PROJECT STATUS

Phase I activities--preparation of a BES technology and cost data bank--are currently ongoing. Nineteen BES technology options have been selected for inclusion in the cost data bank. Six of them are currently being evaluated. A consistent evaluation methodology has been developed to permit a systematic analysis of the options. Up-to-date information on technological developments and equipment costs is being acquired on a continuing basis. The project expenditure to date has been less than scheduled due to the planning nature of the work. For the upcoming quarter, technical and cost analyses will be the major work item and the level of effort is expected to be significantly higher than the previous quarter.

V TECHNICAL PROGRESS

Analyses of BES Technology Options

Nineteen BES technology options have been selected for inclusion in the Data Bank. The selection consists of eleven thermochemical conversion options and eight biochemical options, and covers biomass energy products in the form of electric power, steam, gaseous, liquid, and solid fuels. The selection is given in Table 1 together with the estimated time-frame for the availability

Table 1

TECHNOLOGY OPTIONS SELECTED FOR DATA BANK

<u>Thermochemical Options</u>	<u>Estimate Availability</u>
Electric power generation	Now
Steam generation	Now
Co-generation	Now
Densification	Now
LBG (low pressure)	Now
IBG (low pressure)	By 1985
SNG	By 1985
Pyrolytic liquid products	By 1985
Methanol	By 1985
Catalytic liquefaction	Beyond 1985
Hydrocarbons from plants	Beyond 1985
<u>Biochemical Options</u>	
Ethanol from sugar crops	Now
Ethanol from corn crops	Now
SNG and IBG from manure	Now
Continuous fermentation	Now
Ethanol from wood	By 1985
Ethanol from crop residues	By 1985
Ethanol from aquatic biomass	Beyond 1985
SNG from kelp	Beyond 1985

of the options. "Availability" in this instance refers to the readiness of the process technology for commercialization. Actual commercialization of BES technologies will depend on additional market, institutional, comparative economic, and available resource considerations, and will be addressed during the upcoming phases of this project. To enhance the timeliness and utility of the data bank, the majority of the selected options in Table 1 are deemed to be available now or in the near-term.

At present, six of the options--ethanol from wood, electric power, steam, co-generation, pyrolysis liquids, and catalytic liquefaction--are being analyzed. The results are expected shortly.

Evaluation Methodology

A consistent methodology has been developed to permit a systematic analysis of the technology options. The basic approach is to:

- Take maximum advantage of existing SRI and literature process and cost information.
- Update information.
- Generate base case estimates.
- Apply judgment to arrive at high/low estimates.
- Make sensitivity runs with computer program.
- Identify and discuss key factors contributing to uncertainty.
- Corroborate findings with appropriate outside sources.

For each option, the output will include:

- Process description, including current status of development.
- Block flow diagram showing major process steps, feed and product identifications and rates.
- Process Summary sheet (Table 2).
- Capital cost investment table for base/high/low cases.
- Operating cost table for base/high/low cases.
- Product cost table for base/high/low cases.
- Discussion of key uncertainties.

Table 2

PROCESS SUMMARY SHEET

Technology Option _____

Available Date _____

<u>Feedstock</u>	<u>Rate</u>	<u>Unit Cost</u>
_____	_____	_____

Products

_____	_____	_____
_____	_____	_____
_____	_____	_____

Principal Energy FlowsInputMMBtu/HrPercent

Feedstock(s) _____

Purchased electricity _____

Total

100

Output

Product _____

Product _____

Product _____

Heat rejected to cooling _____

Stack losses _____

All Other _____

100

Major Operating Requirements

Operating labor, Men/shift _____

Fresh water, gpm _____

Purchased electricity _____

Others _____

Capital Investment Estimates Uncertainties

For an assumed plant capacity, the capital investment estimates are subject to uncertainties due to technical, equipment cost, and plant location factors. These uncertainties will be quantified as follows:

Technical Uncertainties

For each plant section, high and low estimates of the probable error will be derived and expressed as percent of the base case estimate. Aggregate conclusions will be drawn, based on sound engineering judgment, and the following considerations:

- Approximately 90 percent confidence level
- Process efficiency
- Status of development of the process
- Plant turndown ratio
- Flow rates variations
- Process conditions changes
- Design safety margin
- Design redundancy (back-up systems)
- Degree of conversion
- Feedstock uniformity
- Waste heat utilization
- Utilities peak loads
- Product specifications
- By-products handling
- Emissions controls
- Outlook for process optimization and improvement

A set of illustrative error estimates is given below:

<u>Status of Process</u>	<u>PFI Technical Uncertainties (percent)</u>
Commercial	5 - 15 %
Demonstration	15 - 30
Pilot Plant	25 - 50
PDU	50 - 75
Pre-development	60 - 140

Equipment Cost Uncertainty

In general, equipment costs based on vendor quotes or open literature are good to within 25 to 35 percent. Experience has shown that most vendors tend to understate the costs when giving out quotes so that a range of -5 percent to +25 percent may be a good estimate of the equipment costs uncertainty. For complex equipment, installation and testing costs may introduce more uncertainty. For equipment which is not yet available commercially, special design and fabrication will be required and the costs will be subjected to even greater uncertainties. An illustrative set of equipment cost uncertainties is given below.

<u>Equipment</u>	<u>Uncertainty (percent)</u>	
Commercial--proven	- 5 %	+ 25 %
Commercial--modification required	- 5	+ 30
Under development	- 10	+ 40
Conceptual	- 25	+ 60

Plant Location Uncertainty

Variations in the local construction costs present another source of uncertainty for capital investment estimates. This variation may be expressed as a construction index and applied to the PFI investments.* Based on the likely areas for biomass conversion plants, the probable range of variation for construction cost is estimated to be in the range of -5 percent to +15 percent (reference = USGC).

Overall Uncertainty Estimate for PFI

The uncertainty estimates for the three above stated categories are considered independently using the base case estimate as the frame of reference. The probable overall error can then be obtained by the statistical method outlined below.

In considering the technical, equipment, and location uncertainties, it may be concluded that the cost variations due to technical and equipment uncertainties are more likely to exhibit a random occurrence characteristic than the location variation. That is to say, if a plant is located in an area of high construction cost, it is likely that each plant section will require high investment. However, it is quite probable that one plant section will end up costing

* PFI = Plant Facilities Investment

more while another one ends up costing less due to technical and equipment cost uncertainties. Based on this rationale, the cost variations due to the technical and equipment costs should be combined statistically and then the adjustment for the plant location can be made. The procedure is given below:

(a) Technical and equipment uncertainty*

Let E = error - %

Subscript c = combined

e = equipment

t = technical

$$E_c = \sqrt{E_e^2 + E_t^2}$$

For each plant section the high and low estimate can then be estimated.

Example: Wood receiving section

Base case = \$10 MM

Tech uncertainty -10% to +15%

Equipment uncertainty -5% to +25%

$$\text{Error (low)} = \sqrt{(10)^2 + (5)^2} = 11.18\%$$

$$\text{Error (high)} = \sqrt{(15)^2 + (25)^2} = 29.15\%$$

$$\begin{aligned} \text{Low estimate} &= 10 \times \left(1 - \frac{11.18}{100}\right) \text{ \$MM} \\ &= \$ 8.88 \text{ MM} \end{aligned}$$

$$\text{High estimate} = \$ 12.92 \text{ MM}$$

(b) Plant location uncertainty

Use multiplier approach.

Example: Location uncertainty -5% to +15% (continuing from last example)

$$\begin{aligned} \text{Overall low estimate} &= \$ 8.88 \times \left(1 - \frac{5}{100}\right) \text{ \$MM} \\ &= \$ 8.44 \text{ MM} \end{aligned}$$

* From propagation of Error Theory.

$$\begin{aligned}\text{Overall high estimate} &= \$ 12.92 \times \left(1 + \frac{15}{100}\right) \$\text{MM} \\ &= \$ 14.86 \text{ MM}\end{aligned}$$

(c) General Estimation Formula

$$C = C_o (1 \pm E_l) \left[1 \pm \sqrt{E_e^2 + E_t^2} \right]^*$$

where C_o = Base case capital investment estimate

C = High or low estimate

E = Percent uncertainty $\frac{\cdot}{e} \cdot 100$

Subscripts: e = equipment

l = location

t = technical

To keep the format consistent, a standard table has been prepared, (Table 3).

Operating Cost Uncertainties

Operating costs can be analyzed by categorizing the cost components:

- Biomass feedstock cost
- Other operating supplies (e.g., catalyst, chemicals, etc.)
- Maintenance supplies
- Labor (all labor and burden)
- Fixed costs (G&A, property tax and insurance, EXCLUDING DEPRECIATION)
- Purchased utilities (power, water, etc.)

Nominal, high, and low estimates will be generated for the components of the operating cost. Plant experience and engineering judgment will be used to define the range of uncertainty for the feedstock cost, operating supplies, and operating labor required. Experience has shown that certain costs (e.g., main-

* Use + for high estimate, - for low estimate.

Table 3

Technology Option _____

Plant Capacity _____

Feedstock:	Rate:
Main Product:	Rate:
By-Product:	Rate:
By-Product:	Rate:

PLANT SECTION	PERCENT				MILLIONS OF DOLLARS		
	Tech. Uncertainty		Equip. Uncertainty		Estimated Investment		
	Low	High	Low	High	Low	Base	High
PLANT FACILITIES INVESTMENT							

	MILLIONS OF DOLLARS		
	Low	Base	High
Plant Facilities Investment			
Royalties			
Land			
Interest During Construction			
Organization & Start-up Expenses			
Working Capital Requirements			
TOTAL CAPITAL INVESTMENT			

tenance labor and supplies, and fixed costs) may be estimated based on PFI, in which cases the error estimates may be derived from the BASE PFI estimate (from the Capital Investment Estimate work) using the high and low percentage estimates of the item in question. For example, maintenance materials costs generally run from 1.5 to 4.0 percent of PFI, thus providing the likely uncertainty range. Some probable uncertainty ranges are given in Table 4. The operating cost may be expressed as ¢/MMBtu of the energy products and the various estimates can be combined statistically. For a consistent reporting format, Table 5 is suggested. The key uncertainties may then be easily identified.

Product Cost Uncertainties

The product cost can be expressed as:

$$\text{Product Cost} = \text{capital related charges} + \text{operating cost} - \text{by-product credits}$$

For this analysis, capital related charges include capital charges (i.e., before tax income for non-regulated producer/return on rate base for regulated producer) and income taxes. Treatment of the capital investment and operating cost have been discussed in the previous section. The capital related charges may be estimated using well known financial analysis methods (e.g., discounted cash flow) and the financial basis given below:

- Financing method
 - non-regulated, 50% to 100% equity
 - regulated, 65% to 75% debt
- Mid-1979 dollars
- For capital investment estimation, assume:

	<u>Percent</u>
General facilities	5-15%
Paid-up royalties	5
• DCF ROR	15
• Construction interest	10
• Long-term debt interest	9
• Construction period--two to four years	
• Project life, 30 years	

Table 4

PROBABLE UNCERTAINTY RANGES FOR SELECTED COST ITEMS

	Nominal	Range
Land	\$5,000 per acre	3,000 - 8,000
Feedstock inventory	30 days	3 - 180 days
Purchased power	3.5¢ per kWh	3 - 4.5
Maintenance labor	2.5	1.5 - 4.0% of PFI
Maintenance materials	2.0	1.0 - 3.0\$ of PFI
Operating labor rate	\$ 8.50 per Hour	+ or - 15%
Supervision	15% of operating labor	10 - 20
Administrative support	20% of O&M labor	15 - 25
Payroll burden	35% of all labor	30 - 40
Federal income tax	46%	as low as 30%
State income tax	5%	0 - 9
Property tax and insurance	2.5% of PFI	2 - 3
General administrative expense	2% of PFI	1.5 - 2.5
Organization and start-up expense	5% of PFI	4 - 7.5
Purchased water	60¢ per 1,000 gallons	40 - 80
Product storage (if applicable)	10 days	5 - 60
Income tax credit	10%	0 - 20

Table 5

OPERATING COST ESTIMATES

Technology Option _____

Plant Capacity _____

Feedstock:	Rate:
Main Product:	Rate:
By-Product:	Rate:
By-Product:	Rate:

Contribution to Operating Cost, ¢/MM Btu

Cost Component	Low	Base	High
Feedstock			
Operating Supplies ⁽¹⁾			
Maintenance Supplies			
Labor Related Charges			
Fixed Costs ⁽²⁾			
Purchased Utilities ⁽³⁾			
Others			
TOTAL OPERATING COSTS			

(1) Including catalysts and chemicals, etc.

(2) Excluding depreciation

(3) Including power, water, etc.

- Tax life, 20 years--regulated producer
15 years--non-regulated producer
- Stream factor, 80%
- Depreciation schedule
 - sum of years digit for non-regulated producer
 - straight line for regulated producer

By-product(s) value(s), in some cases, could have significant impacts on the final cost of the energy product. This is especially evident for biochemical conversion options where the by-products (co-products) may generate as much as 70 percent of the plant revenue requirements and become the pre-dominant contributors to the cost uncertainties. For this study, in-depth investigation of the market value and potential utilization of several important by-products (including lignin, pentosan, fiber, and refeed) will be conducted to better define by-product credits and the associated uncertainties.

Table 6 is the suggested standard format for reporting the product cost. The structure is designed to permit the product cost to be estimated by adding the appropriate cost components for a given assumed scenario. For each component (capital charges, operating cost, etc.), the data bank user may apply subjective judgment as to the expected outcome (high/base/or low) and select the corresponding cost contribution. Then the components can be summed to yield the product cost estimate.

Data Acquisition

SRI Project personnel attended the "Energy from Gasification and Direct Combustion of Wastes and Residues" Workshop sponsored by the Solar Energy Research Institute, the California Energy Commission, and the Western Solar Utilization Network (April 9-10, 1979. Claremont, California). The Workshop covered the current projects, available equipment, financing alternatives, and regulatory issues for the conversion of forest and agricultural wastes and residues to energy.

VI DESCRIPTION OF FUTURE WORK

Technical and cost analyses for the selected BES technology options will continue. The evaluation methodology will be refined as required. Data acquisition is carried out on a continuing basis to assure that the most up-to-date information is utilized. During and upon completion of the analysis for each option, critical comments and reviews are solicited from the leading researchers in the field of interest.

Planning of the regional BES product market penetration study will begin in the next quarter.

Table 6

PRODUCT COST ANALYSIS

Technology Option _____

Plant Capacity _____

Feedstock:	Rate:
Main Product:	Rate:
By-Product:	Rate:
By-Product:	Rate:

Cost Contribution, ¢/MM Btu*

Component			
Capital Related			
Feedstock			
Operating supplies & materials			
Maintenance supplies & materials			
Labor			
Fixed costs			
Purchased utilities			
By-product credit	()	()	()
By-product credit	()	()	()
By-product credit	()	()	()
TOTAL PRODUCT COST			

* All cost components may be selected and combined additively using the "building block" approach.