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Final Report

Appendix E – 1,000 Ton per Day Anaerobic Digestion Plant Case Study

October 1979

Work Performed Under Contract No. EC-77-C-03-1470

Dynatrend Incorporated
Arlington, Virginia

U. S. DEPARTMENT OF ENERGY

Division of Industrial Energy Conservation

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DEVELOPMENT OF A RISK ANALYSIS MODEL
FINAL REPORT
OCTOBER 1979

APPENDIX E
1,000 TON PER DAY ANAEROBIC DIGESTION
PLANT CASE STUDY

prepared for
THE OFFICE OF BUILDINGS AND COMMUNITY SYSTEMS
OFFICE OF THE ASSISTANT SECRETARY FOR
CONSERVATION AND SOLAR ENERGY
DEPARTMENT OF ENERGY

CONTRACT DE-AC03-77CS20158

prepared by
DYNATREND INCORPORATED
1911 North Fort Myer Drive
Arlington, Virginia 22209

DYNATREND INCORPORATED

PREFACE

This document is Appendix E of DYNATREND INCORPORATED's report, "Development of a Risk Analysis Model, Final Report" October 1979, prepared for the Department of Energy's Office of Buildings and Community Systems under Contract DE-AC03-77CS20158. Three case studies were included in the process of the contract effort: Appendix D, "Gas Fired Heat Pump Case Study"; Appendix E, "1000 Ton Per Day Anaerobic Digestion Plant Case Study"; and Appendix F, "District Heating and Cooling System Case Study". Appendix C, "Risk Analysis Methodology", provides general information concerning the model used in the three case studies, its input data requirements, and its output reports.

This appendix presents the findings of studies related to the anaerobic digestion of urban wastes and the extraction of energy from the process. Appreciation is expressed for the excellent cooperation of Mr. Peter Ware and associates of Waste Management, Incorporated.

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CHAPTER 1

INTRODUCTION

1.1 RATIONALE FOR THE STUDY

At a time of strains on the nation's economy which result from the need to import large quantities of fuel, the desirability of recovering energy from waste is obvious. Seeking energy savings, the Department of Energy (DOE) is investigating processes for the recovery of energy from urban wastes, with the intention of determining how the barriers standing in the way of commercialization of these processes can be overcome.

Commercialization of any urban waste energy recovery process is constrained by many complex, uncertain components and interactions. Technical, economic, and institutional barriers presently exist which increase both the real and perceived risks of making such a venture commercially feasible. Current risks applicable to processes of this type may be categorized as follows (Reference 1):

- (1) Performance and reliability of technology;
- (2) Capital, operating, and maintenance costs;
- (3) Recovered product quality and quantity;
- (4) Waste (feedstock) quality and quantity; and
- (5) Market (energy buyer) stability.

In addition to these risks, complex interactions between the municipal sector as generator of waste, private industry as supplier of recovery technology, and the energy and materials markets as buyers of recovered resources, make the process of deciding whether to adopt such a technology extremely difficult. Faced with a possible capital expenditure of many millions of dollars, the municipal sector will surely demand that risk be minimized before adopting a new technology. Thus, until the

technology has proven itself to be technically and economically viable, the Federal sector will most likely be required to assume some of the risk during initial stages of commercialization.

Risk analysis can provide the DOE policy maker with an analytical framework within which the energy from waste venture may be modelled from the perspective of the municipal sector. By seeing this explicit portrayal of the venture, with its attendant risk, the policy maker is able to tailor an optimum Federal program to reduce the particular perceived risks.

One of the energy recovery processes under investigation by DOE, anaerobic digestion, is a biological technique for the production of usable gases from urban waste which provides a degree of promise for producing energy in commercial quantities. As part of a contract to develop a risk analysis methodology suitable for the use of DOE's Office of Buildings and Community Systems (BCS), DYNATREND INCORPORATED carried out a study of an anaerobic digestion process using a risk analysis model which it selected and modified for DOE's use. The specific process analyzed was in experimental operation as a pilot plant in Pompano Beach, Florida.

1.2 THE COMMERCIALIZATION PROCESS

Process oriented technologies such as anaerobic digestion typically proceed through the following steps to commercialization:

<u>Step</u>	<u>Goal</u>
1. Bench-scale experiments	Scientific proof
2. Process development units	Research and development
3. Pilot plant	Engineering confirmation
4. Demonstration or Pioneer plant	Integrated and economical operation
5. Commercial facilities	Competitive volume and price

These sequential steps comprise a scale-up process whereby technical processes are tested and verified in facilities of increasing size. The pilot plant stage is often considered to be the ". . . most significant step in this sequence because it is a scale at which technical risk, engineering, and cost bases are verified with commercial components for application at the stepped-up scale of a pioneer plant."(Reference 2). Note that there is a direct relationship between the perception of commercialization risk and the number of preceding scale-up steps. For example, a technology proceeding directly from the pilot plant stage to the commercial facility stage would probably be perceived as being more risky than one that had passed through the demonstration phase. The technology investigated, now in the pilot plant stage, retains a significant amount of risk. Quantification of the risk and identification of sources of the risk can be expected to assist in the development of remedies and to speed the process toward the commercial stage.

1.3 DOE'S ROLE IN THE COMMERCIALIZATION PROCESS

DOE's role in the commercialization of urban waste technologies is delineated in the Draft Commercialization Strategy Report submitted by the Urban Waste Technology (UWT) Commercialization Task Force, August 31, 1978. As depicted in Appendix D of this report for the Gas-Fired Heat Pump, the basic DOE role may be summarized as that of ensuring that the technology's risk versus return is acceptable to the targeted market segment, in this case the municipal sector.

The Federal role is broadly defined as ensuring the timely commercialization of waste to energy systems by reducing the following impediments (Reference 3):

- "o project risks
- o demanding, time consuming, and costly project implementation

- o competition from waste disposal alternatives
- o aggregation and control of wastes
- o stringent and costly project financing procedures."

The UWT Commercialization Task Force recommended several major program activities designed to overcome these barriers, including (Reference 4):

- "o implementing a revolving loan fund and other financial incentives
- o continuing a Research, Development and Demonstration Program
- o providing a training and technical assistance program
- o resolving coordination issues with federal, private industry, and state and local governmental units."

During the conduct of this case study, a meeting was held with Waste Management Inc.; the designers, builders, and operators of the Pompano Beach pilot plant or "proof-of-concept facility"; to obtain required data for the risk analysis. Discussion during that meeting touched on the subject of the proper role for the Federal government to assume in promoting commercialization of this anaerobic digestion technology. Waste Management personnel identified the following areas for possible governmental involvement:

- o research into environmental and health aspects of the technology;
- o providing grants to the municipal sector to promote the technology and remove some of the planning burden;
- o education of the public sector by effective dissemination of information; and
- o subsidies to lower the tipping fee until the technology is economically competitive with competing land fills.

Several of the issues raised in this section readily fit into the risk analysis framework used. Possible DOE strategies to overcome barriers to commercialization will be examined within this report.

1.4 THE ROLE OF RISK ANALYSIS IN COMMERCIALIZATION CASE STUDY

This case study of anaerobic digestion of urban waste analyzes, from the perspective of municipal ownership, the financial ramifications resulting from construction of a 1,000 ton per day commercial scale-up of the existing Pompano Beach pilot facility. Private sector involvement is assumed to occur in the form of a "full-service contractor" with responsibility for design, construction, and operation of the facility.

By modelling the financial structure of the venture including explicit consideration, using subjective probability distributions, of key uncertain variables, risk analysis is able to present the decision maker with a quantified picture of the venture's expected financial outcome. In addition, through the process of sensitivity analysis, one is able to gauge the change in venture outcome resulting from a change in a key input variable. It is possible to model uncertainties in performance and reliability of technology; capital, operating, and maintenance costs; recovered product quantity; waste (feedstock) quantity; etc.; and to gauge their individual impact on the project's financial outcome.

Once the venture has been modelled and the sensitivity analysis completed, it is then possible to analyze the impact of various governmental strategies on the venture's risk and return.

In considering the results of this case study, it must be emphasized that energy from urban waste technologies are highly

site specific. The risk analysis procedure, however, is very flexible, requiring only adjustments to input data to account for the site selection.

CHAPTER 2

THE ANAEROBIC DIGESTION PROCESS

2.1 BACKGROUND

Anaerobic digestion of refuse and refuse-sewage sludge mixtures has been investigated on a laboratory scale for over 9 years. In 1969, the Environmental Protection Agency funded bench-scale studies (5-15 liter digesters) at the University of Illinois, Urbana Champaign, by Dr. John T. Pfeffer. The Research Applied to National Needs program of the National Science Foundation funded a follow up study at UIUC in 1973 which used a 400 liter (100 gallon) capacity mechanical-stirred fermentor. These studies indicated that methane gas produced by anaerobic fermentation of the organic fraction of the refuse could be price competitive with alternative sources of natural gas.

As a result of Pfeffer's positive findings, the National Science Foundation awarded a contract to the Dynatech Corporation in 1973 to develop a preliminary design and an economic model for a full-scale (1,000 tons per day) plant. The Dynatech study indicated that methanation of urban waste would prove technically feasible at a cost competitive with available sources of natural gas. Moreover, the study pointed out the need to go beyond the bench-scale-analytical study phase. Construction and operation of a practical sized scale-up was necessary to determine actual production and purification costs.

Following the usual practice of constructing a pilot or proof-of-concept facility to study process and engineering factors before large-scale commercialization of the system, the Department of Energy awarded a contract in 1975 to Waste Management Inc. to design and construct such a facility. Waste Management chose to locate the plant in Pompano Beach, Florida, adjacent

to an existing waste-shredding facility which it owned and operated.

The Pompano Beach plant was completed and experimental operations begun in the summer of 1978. It uses an anaerobic digestion process in which bacteria, in the absence of air, break down solid organic wastes and cause formation of methane-rich gas. The organic matter in typical solid waste is observed to be predominantly cellulose. The chemical reaction which takes place is as follows:

2.2 POMPANO BEACH FACILITY

The Pompano Beach plant is capable of processing 50 to 100 tons per day of urban waste. Feedstock consists of the light organic fraction of solid wastes along with five percent sewage sludge. The process flow diagram for the present proof-of-concept plant is illustrated in Figure E-1.

The facility has been constructed to meet the following engineering and technical goals:

- o Identify and resolve equipment performance problems. Extensive failure test analyses will identify equipment components requiring design changes to improve operational facilities.
- o Refine procedural aspects of the system to reduce the total cost of operation. This includes analysis of work stations and sequential steps associated with refuse processing.

By focusing on process optimization, the Pompano Beach facility will advance the anaerobic digestion process toward ultimate commercialization and assist in reducing institutional economic barriers to success.

Source: Project Summary, Contract No. EY-76-C-02-2770, A.S.E.F.
Solid Waste to Methane Gas - Pompano Beach, Florida,
Waste Management, Inc.

FIGURE E-1. FLOW PROCESS DIAGRAM OF POMPANO BEACH FACILITY

It is estimated that a 1,000 ton per day plant such as that analyzed in this case study could produce enough methane to serve the gas needs of 10,000 homes and simultaneously reduce the volume of waste processed by 70%.

2.3 BARRIERS TO COMMERCIALIZATION

2.3.1 Geographical

At the present time, private industry sources perceive anaerobic digestion (a.d.) as being geographically limited. This perception occurs because of economic requirements to locate an a.d. facility in an area where landfill capacity is diminishing and where a ready market exists for the processed end-products, methane and carbon dioxide. Major urban areas of the East Coast meet these constraints and are prime candidates for adopting this technology. However, other geographical areas will enter the potential market only as existing landfill capacity and endogenous energy sources diminish.

2.3.2 Economic-Capital Costs

Waste Management, Incorporated indicated that it would not be interested in owning a 1,000 ton per day a.d. facility due to the burden of carrying a large capital investment on its balance sheet. The company would prefer to act as a full service contractor, using its management and engineering expertise to design, build, and operate a.d. plants. Given this attitude on the part of a private company deeply involved in the urban waste field, it would appear that the municipal sector would become the primary market for this technology. Other ownership scenarios such as third party ownership-leasing and franchise arrangements may be possible, but are beyond the scope of the present study.

Construction of a full scale commercial a.d. facility is estimated by Waste Management to require a capital expenditure of approximately \$50 million. Approval of the expenditure of such a large sum by a municipality will present a barrier to the technology's commercialization. In addition to the costs of actual construction, approval would initially be required for substantial municipal expenditures for initial planning and for preparing documentation to support a sizeable bond issue.

2.3.3 Economic-Revenue

The economic viability of the process hinges on the supply and demand for urban waste disposal services, methane (natural gas), and carbon dioxide. Efficient operation of the process is predicated on having a sufficient flow of refuse to the a.d. facility. It is anticipated that each ton of refuse accepted by the plant will be handled for a fee known as the tipping fee. This fee and the revenue from the sale of methane and carbon dioxide must cover operating expenses, debt service, disposal of the solid waste remaining after extraction of the energy product, and any profit. The tipping fee must be economically competitive with costs of conventional waste disposal methods in order to establish a market for the process.

2.3.4 Environmental

No insurmountable environmental barriers are envisioned for this process. Environmental data must be collected on process air emissions, waste water streams, and solid waste residue. Characterization of the waste water stream is required to determine its quantity and quality since it is suspected to be high in both organic and inorganic matter. Solid waste residue and air emissions must similarly be characterized to ensure they meet EPA regulations being formulated under the Resource Conservation and Recovery Act of 1976.

2.3.5 Institutional

Institutional barriers represent the most serious potential obstacles to successful commercialization of a.d. energy recovery facilities. These barriers encompass a broad range of jurisdictional, legal, political, and regulatory difficulties which must be thoroughly analyzed before implementation of the technology can proceed. The Commercialization Strategy Report (UWT Commercialization Task Force, August 31, 1978) identified some of these institutional barriers:

- o Perception of Municipal Officials Toward Solid Waste -Most municipal officials do not view solid waste as a potential resource. Therefore, they focus their attention on solving a disposal problem, rather than considering broader resource use questions.
- o Control and Quantification of the Waste Stream - A viable facility requires a guaranteed supply of waste. Private sector refuse haulers oppose any attempt to legislate waste flow control. Depending upon the outcome of current litigation, Federal subsidies may be required to encourage haulers to use a.d. facilities.
- o Municipal Procurement Practices - Most current municipal procurement is the straight-forward acceptance of the lowest bid for a well defined item or work package. Because of the characteristics of new technologies, flexibility is required in these practices in order to deal with possible innovative contracting procedures such as full service contracting, third party leasing, franchise arrangements, etc.
- o Regulatory/Political - Potential conflicts concerning oversight functions must be resolved since the facility involves environmental and energy components and produces a potential food additive (CO₂).

CHAPTER 3

METHODOLOGY AND INPUT DATA

3.1 STUDY METHODOLOGY

The procedures employed in the computations of the risk analysis model developed for the use of DOE's Office of Buildings and Community Systems are described in the main report, with further detail provided in Appendix C, Risk Analysis Methodology.

Performing a case study of the commercialization potential of anaerobic digestion technology presented some unique problems. The present proof-of-concept facility in Pompano Beach is not of a commercial scale. Therefore, it was necessary to obtain informed judgements concerning costs for a hypothetical commercial 1,000 ton per day scale-up of the current facility. Thanks to the cooperation of Mr. Peter Ware and his associates at Waste Management, Inc. (W.M.I.), the derivation of this data was possible. In addition, the assumptions to use for modelling the case study could be selected.

The 1,000 ton per day facility was assumed to be owned by a municipal entity responsible for acquisition of required capital, supply of waste to the facility and its disposal for a set fee, and sales of certain process end-products. Private sector involvement was assumed to take place in the form of a full service contractor responsible for design, construction, operation, and maintenance of the facility. Based on the preceding assumptions, a base case was derived which represented financial outcomes of the venture to the municipal entity without Federal assistance. A majority of the input data reflects best estimates of W.M.I. personnel.

Arriving at a value model to use in judging venture acceptability was not as clear cut as it would be in a private sector case.

The base case was modelled such that the tipping fee per ton would cover debt expenses as well as plant operation and maintenance costs. However, in reality this tipping fee may have to be scaled down in order to promote the technology. Thus, the revenue resulting from sales of methane and carbon dioxide are potentially critical to the economic viability of the venture. As presently constituted, the venture would be judged acceptable provided it could operate independently with no additional funding from any source. Public sector present value analysis is quite controversial. The majority of the controversy centers around the proper public sector discount rate to be used. This problem was dealt with by calculating the present value of the venture at several possible discount rates.

The computer analysis phase of the anaerobic digestion case study proceeded from the creation of a base case, using the best data available. Results of the base case analysis served as a point of reference. The sensitivity analysis and the policy analysis were then carried out.

Sensitivity analysis is generally performed, in a deterministic analysis, by holding all variables constant except for the one uncertain variable under study. The variable under study is then varied to examine the impact of its uncertainty on the final evaluation criteria. This procedure highlights areas where additional information is required and where effort should be expended to reduce the uncertainty of the outcome. In the risk analysis, uncertainty is explicitly dealt with in arriving at input data by the selection of the range (maximum and minimum values) and the uncertainty profile, which depicts the subjective probabilities of the variable occurring at particular values within that range. Because the selected range encompassed all probable values, the sensitivity analysis performed for this case study consisted of determining the effect of the choice of probability distributions, or

uncertainty profiles, on the venture's outcome. The uncertainty profiles used are illustrated in Figure E-2.

Policy analysis consists of the examination, in a similar manner, of the variables which are subject to modification as a result of Federal policy actions.

3.2 BASIS FOR COMPUTER MODEL INPUT DATA

As stated previously, the major source of data used for the base case simulation was Mr. Peter Ware of Waste Management, Inc. During a meeting at W.M.I.'s corporate headquarters on February 28, 1979, Mr. Ware and his associates were questioned concerning required risk analysis input. Minutes of that meeting are attached to this appendix for reference (Attachment 1). Particular attention should be paid to W.M.I.'s perception of the state of the technology and the possible Federal role in its evolution.

Data obtained from outside sources or data requiring further explanation are noted in Table E-1. Variables are defined in the DOE Adaptation of the Risk User's Manual. Uncertainty profiles were chosen to reflect a reasonable level of conservatism.

FIGURE E-2. UNCERTAINTY PROFILES

TABLE E-1. BASE CASE DATA

<u>Section</u>	<u>Variable</u>	<u>Assumptions</u>	<u>Source/Reference</u>
1	MAXPR=3	Venture assumed to have three major sources of revenue--tipping fee, sale of methane, sale of CO ₂	
1	DELMIN=0.0 DELMAX= .5	Start of sales assumed to occur 1985 to 1985 +.5 years	
5	PRICEO PMING PMAXO	Tipping fee calculated to cover operating expenses, debt service, and disposal of remaining wastes. This resulted in an initial tipping fee range from \$23.75 to \$41.34/ton, with \$33.55/ton most likely, escalated to 1985.	
	UNO UMINO	Operating days assumed to vary from 312 to 365 with 330 most likely @ 1000 tons per day guaranteed	
	PRICE1 PMIN1 PMAX1	Projected raw natural gas prices. Due to recent price increases in the price of imported oil, data was modified. Prices assumed to vary from \$3.33 to \$3.66/1000 ft ³ with \$3.59/1000 ft ³ most likely	DOE/BCS supplied energy price scenario
	UN1 UMIN1 UMAX1	Methane production assumed to occur at the rate of 3000 ft ³ per ton. All production assumed sold.	Mr. Peter Ware-Waste Management, Inc., Oakbrook, IL
	PRICE2 PMIN2 PMAX2	Current price of CO ₂ assumed=\$.34 per thousand cubic feet. Escalation most likely=4% per year; min=3% per year; max=8% per year	Mr. Ray Savage-Air Products & Chemicals, Inc., Allentown, PA

TABLE E-1. BASE CASE DATA (Continued)

<u>Section</u>	<u>Variable</u>	<u>Assumptions</u>	<u>Source/Reference</u>
E-18 DYNATREND INCORPORATED	5	UN2 UMIN2 UMAX2	CO ₂ production assumed to occur at the rate of 3000 ft ³ per ton. All production assumed sold.
	9	EXMIN6	Straight line amortization of \$50 million in bonds @ 6% interest
		EXMAX6	Straight line amortization of \$50 million in bonds @ 7% interest
		EXMIN7 EXMAX7	Contractor's fee assumed equal to 20% of operating expenses
	10	CPT=1	No depreciation assumed for plant. Considerable controversy exists concerning the proper treatment of depreciation in nonbusiness organizations. The position adapted for the base case was between the two extremes (i.e., debt service expense approximates amounts that would be charged under a depreciation mechanism)
	12	CSHP	Cash assumed to be 20% of current assets
		RECP	Assumed 30 days of sales
		PAYP	Assumed 45 days
			Mr. Peter Ware-Waste Management, Inc., Oakbrook, IL
			Mr. Peter Ware-Waste Management, Inc., Oakbrook, IL

Mr. Peter Ware-Waste Management, Inc., Oakbrook, IL

The Capital Budgeting Decision-4th Edition-Bierman, H. & Smidt, S.-MacMillan Publishing Co., Inc., 1975, p. 120

Mr. Peter Ware-Waste Management, Inc., Oakbrook, IL

Research Report-Financial Accounting in Nonbusiness Organizations-Financial Accounting Standards Board, 1978, p. 146

Waste Management, Inc.-Annual Report, 1978

Prospectus-Connecticut Resources Recovery Authority, Greater Bridgeport System Bonds, Series A, September 9, 1976

CHAPTER 4

DISCUSSION OF BASE CASE RISK ANALYSIS RESULTS

The anaerobic digestion base case was modelled from the financial perspective of a municipality considering the possibility of constructing and operating a 1,000 ton per day anaerobic digestion facility. It should be noted that the analysis concentrated on gauging the impact of energy and CO₂ recovery. Other potential resource recovery possibilities (e.g. metals, glass, aluminum) were not addressed. This exclusion is due to the very site specific nature of resource recovery, making generic assumptions questionable, and is considered to be a conservative aspect of the analysis.

By examining Figures E-3 and E-4, one is able to perceive some of the potential financial ramifications of the venture. First, the major outlay of capital during planning and construction of the plant may be seen by many municipalities as a significant barrier to the venture. Second, the annual average before-tax profit is seen to turn positive in year four and to increase steadily throughout the life of the facility. This profit is due mainly to sale of methane and carbon dioxide, since the tipping fee was calculated to cover operating expenses and debt service.

From an overall discounted cash flow sense, the venture appears favorable. Table E-2 indicates an internal rate of return to a municipality of approximately 7 percent after debt service. However, it must be remembered that the base case assumed a guaranteed supply of waste and a guaranteed market for end-products at their projected market price.

Potential energy savings from an anaerobic digestion plant result from production of methane. After clear-up, this gas has been demonstrated to be pipeline quality (1,000 BTU/ft³). A 1,000 ton per day anaerobic digestion facility is projected

FIGURE E-3. BASE CASE-CASH FLOW RISK PROFILE

FIGURE E-4. BASE CASE-BEFORE TAX PROFIT RISK PROFILE

TABLE E-2

RISK PROFILE DATA
PRESENT WORTH
(THOUSANDS OF DOLLARS)

Percent Chance
of Exceeding
Indicated
Amount

0	83967.6	26197.1	9165.6	-3023.9	-11156.6
4	79021.8	23093.5	7422.7	-3623.5	-12077.2
8	77626.9	22058.9	5679.8	-5272.3	-13573.2
12	76612.4	20852.0	4808.4	-6583.8	-14608.9
16	75788.0	20162.3	3812.4	-7627.7	-15989.8
20	75027.1	19546.5	3314.5	-8056.0	-16296.7
24	74184.7	18955.3	2816.5	-8519.9	-16603.5
28	73315.2	18364.1	2318.5	-9019.6	-16852.9
32	72554.3	17846.8	2030.6	-9219.4	-17083.0
36	71793.4	17551.3	1812.8	-9419.3	-17313.2
40	69933.4	17255.7	1594.9	-9619.1	-17577.8
44	69257.1	16960.1	1377.1	-9893.9	-17854.0
48	68532.4	15334.4	160.7	-10393.6	-18233.8
52	67662.9	14535.0	-420.3	-11267.9	-18820.7
56	66467.2	14158.8	-856.0	-11567.7	-19096.8
60	65097.7	13782.6	-1291.8	-11867.5	-19373.0
64	63931.0	13092.9	-1789.7	-12267.2	-19738.0
68	62916.6	12489.4	-2308.4	-12766.8	-20132.5
72	62010.6	11972.1	-2889.4	-13099.9	-20527.1
76	61141.1	1196.2	-3361.4	-13433.0	-20892.0
80	60126.5	10383.3	-3797.2	-13891.0	-21168.2
84	58604.8	9792.2	-4279.6	-14415.6	-21444.4
88	56322.1	8868.5	-4777.6	-15015.2	-22031.3
92	55307.6	7230.4	-6520.5	-16514.1	-23584.8
96	53024.9	6023.5	-7827.6	-17638.3	-24620.5
100	45923.4	333.4	-12620.6	-21760.3	-28418.0
	2.0	6.0	8.0	10.0	12.0
	DISCOUNT RATE (PERCENT)				
AVERAGE(\$1000)	67293	14995	-208	-10970	-18598
STD.DEV.(\$1000)	7975	5185	4377	3791	3351

to produce about three million cubic feet of methane per day. This quantity of energy could be used to conserve an equivalent amount of natural gas. Table E-3 presents the present worth of natural gas conserved by constructing and operating such an anaerobic digestion facility.

TABLE E-3

RISK PROFILE DATA
PRESENT WORTH
OF ENERGY SAVINGS OF TYPE 1
(THOUSANDS OF DOLLARS)

Percent Chance
of Exceeding
Indicated
Amount

0	18194.6	11841.8	9730.7	8086.5	6791.0
4	17817.0	11598.5	9518.4	7888.4	6624.6
8	17756.1	11564.5	9493.5	7866.4	6601.3
12	17723.6	11510.9	9445.3	7829.7	6565.3
16	17683.0	11476.9	9427.5	7817.5	6554.4
20	17650.5	11448.3	9408.1	7797.6	6538.1
24	17634.2	11432.4	9387.3	7765.5	6505.4
28	17818.0	11416.5	9356.1	7750.0	6491.6
32	17600.1	11400.6	9344.8	7741.5	6484.1
36	17580.6	11384.7	9333.4	7733.1	6476.6
40	17551.2	11371.2	9322.1	7721.0	6464.6
44	17536.8	11360.2	9310.7	7705.2	6448.3
48	17512.4	11349.2	9299.4	7692.1	6437.5
52	17498.5	11333.8	9281.2	7679.9	6426.6
56	17484.6	11305.2	9259.9	7667.7	6416.5
60	17470.7	11294.2	9249.5	7655.5	6406.7
64	17449.8	11283.2	9239.1	7543.5	6396.3
68	17421.9	11272.1	9227.8	7532.5	6384.1
72	17396.7	11254.1	9213.9	7621.5	6370.8
76	17372.3	11233.6	9200.1	7602.3	6354.5
80	17285.0	11205.0	9175.1	7577.5	6335.7
84	17207.9	11162.1	9122.0	7529.4	6301.5
88	17155.1	11090.5	9075.2	7472.0	6240.3
92	17155.1	11019.0	9012.8	7472.0	6240.3
96	17155.1	11019.0	9012.8	7472.0	6240.3
100	16976.4	10947.4	8950.4	7398.7	6179.1
	2.0	6.0	8.0	10.0	12.0
	DISCOUNT RATE (PERCENT)				
AVERAGE(\$1000)	17563	11374	9322	7726	6471
STD.DEV.(\$1000)	221	166	148	133	121

CHAPTER 5

DISCUSSION OF SENSITIVITY ANALYSIS RESULTS

Table E-4 and Figures E-5, E-6, and E-7 present the results of the sensitivity analysis. They indicate that the venture is particularly sensitive to uncertainty profiles assumed for tipping fee price, tipping fee units sold, and the utilities expense. Table E-4 also indicates the relative insensitivity of the internal rate of return of the venture to the particular uncertainty profiles chosen. No single profile change results in an internal rate of return greater than 8%.

There is a relative insensitivity of venture outcome to the uncertainty profile assumed for methane price as compared to the change that results when the profile for carbon dioxide price is varied. This occurs because of the ranges assumed for these two variables.

The venture appears to be sensitive to the uncertainty profile assumed for the utilities expense. However, the difference between the base case and the most conservative profile does not appear to be significant. Debt expense was derived by assuming an interest rate range between 6% and 7%. Table E-4 indicates that the financial effects of skewing the distribution toward either rate are not excessive from an overall venture standpoint.

TABLE E-4. SENSITIVITY ANALYSIS RESULTS

Section	Variable Considered	Base Uncertainty Profile	Uncertainty Profiles Investigated	Impact on Venture						
				Discount Rate (%)	Present Worth				Median Payback Period	
					2	6	8	10		
E-26	Tipping Fee Price	12	1	Base Case	Avg. (\$1000)	67293	14995	-208	-10970	Quarter 4
					σ (\$1000)	7975	5185	4377	3791	Year 15
				Avg.	40195	-2062	-14008	-22269	Quarter 3	
				σ	6800	4489	3832	3358	Year 18	
			5	Avg.	50786	4605	-8612	-17851	Quarter 2	
				σ	6139	4096	3518	3100	Year 17	
			21	Avg.	93685	31537	13149	-50	Quarter 1	
				σ	7521	4912	4133	3599	Year 14	
	5	Tipping Fee Units Sold	12	1	Avg.	59498	10098	-4168	-14211	Quarter 3
					σ	7639	5027	4255	3692	Year 16
				21	Avg.	74997	19836	3704	-7768	Quarter 2
					σ	8167	5309	4480	3877	Year 15
5	Methane Price	12	1	Avg.	66054	14195	-863	-11512	Quarter 1	
				σ	7988	5191	4380	3792	Year 16	
			21	Avg.	68545	15801	450	-10425	Quarter 4	
				σ	7971	5180	4372	3786	Year 15	

TABLE E-4. SENSITIVITY ANALYSIS RESULTS (Continued)

Section	Variable Considered	Base Uncertainty Profile	Uncertainty Profiles Investigated	Impact on Venture					
				Discount Rate (%)	Present Worth		8	10	Median Payback Period
					2	6			
5	Methane Units Sold	12	1	Avg. σ	65385 8000	13753 5201	-1230 4390	-11820 3801	Quarter 1 Year 16
			21	Avg. σ	69232 7980	16254 5184	825 4375	-10110 3788	Quarter 3 Year 15
5	CO ₂ Price	1	12	Avg. σ	68616 7997	15778 5198	405 4387	-10482 3798	Quarter 4 Year 15
			21	Avg. σ	69942 8010	16567 5203	1025 4390	-9990 3799	Quarter 4 Year 15
5	CO ₂ Units Sold	12	1	Avg. σ	67026 7975	14825 5185	-347 4377	-11085 3791	Quarter 4 Year 15
			21	Avg. σ	67557 7979	15164 5187	-70 4379	-10856 3792	Quarter 4 Year 15
9	Maintenance Expense	12	1	Avg. σ	68406 7967	15701 5178	364 4371	-10500 3786	Quarter 4 Year 15
			21	Avg. σ	66173 7979	14286 5189	-784 4382	-11443 3795	Quarter 1 Year 16

TABLE E-4. SENSITIVITY ANALYSIS RESULTS (Continued)

Section	Variable Considered	Base Uncertainty Profile	Uncertainty Profiles Investigated	Impact on Venture					Median Payback Period
				Discount Rate (%)	Present Worth				
					2	6	8	10	
E-28	Labor Expense	12	1	Avg. σ	67963 7963	15420 5176	136 4370	-10686 3785	Quarter 4 Year 15
			21	Avg. σ	66637 7977	14578 5187	-547 4379	-11248 3793	Quarter 4 Year 15
	Utilities Expense	25	1	Avg. σ	76410 7962	20580 5152	4248 4343	-7369 3757	Quarter 2 Year 15
			21	Avg. σ	65094 8039	13645 5237	-1287 4422	-11842 3828	Quarter 1 Year 16
E-28	Disposal Charge	15	1	Avg. σ	71374 7956	17576 5168	1884 4362	-9252 3777	Quarter 3 Year 15
			21	Avg. σ	63114 7989	12355 5198	-2348 4389	-12725 3801	Quarter 2 Year 16
E-28	Debt Expense	12	1	Avg. σ	68207 7953	15737 5165	468 4359	-10348 3774	Quarter 4 Year 15
			21	Avg. σ	66388 8036	14260 5210	-878 4399	-11585 3808	Quarter 11 Year 16

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DYNATREND INCORPORATED

TABLE E-4. SENSITIVITY ANALYSIS RESULTS (Continued)

Section	Variable Considered	Base Uncertainty Profile	Uncertainty Profiles Investigated	Impact on Venture					
				Discount Rate (%)	Present Worth				Median Payback Period
					2	6	8	10	
9	Contractor's Fee	12	1	Avg.	69436	16355	895	-10062	Quarter 3
				σ	8001	5202	4390	3800	Year 15
			21	Avg.	65122	13622	-1321	-11883	Quarter 1
				σ	7971	5179	4371	3785	Year 16
10	Capital Expenditure No. 3	16	1	Avg.	67757	16115	1059	-9621	Quarter 3
				σ	7965	5167	4361	3779	Year 15
			21	Avg.	66831	13882	-1468	-12310	Quarter 1
				σ	7985	5260	4488	3933	Year 16

FIGURE E-5. SENSITIVITY OF CASH FLOW TO TIPPING FEE UNCERTAINTY PROFILE

FIGURE E-6. SENSITIVITY OF BEFORE-TAX PROFIT TO TIPPING FEE UNCERTAINTY PROFILE

FIGURE E-7. SENSITIVITY OF BASE CASE NET PRESENT VALUE TO TIPPING FEE UNCERTAINTY PROFILE

CHAPTER 6

LEARNING - EXPERIENCE CURVE ENHANCEMENT

6.1 INTRODUCTION

The rationale and use of learning-experience curves is explained in detail in Appendix D of this report, Gas-Fired Heat Pump Case Study. Learning-experience curves can be applied to this analysis and their effects on venture outcomes can be examined.

Anaerobic digestion of urban waste is principally a process oriented technology. Due to its process basis, it is possible to infer learning-experience effects from "similar" technologies such as chemical and petroleum refining.

Learning-experience curves have been observed for a number of processes. Hirschman (Reference 5) presented evidence of learning-experience effects in the performance of individual process units (see Figures E-8 and E-9), in process start-up operations after repair shutdown periods, in maintenance operations (see Figures E-10 and E-11), and in construction.

The Boston Consulting Group collected historical data on experience curve behavior of a number of process based products including motor gasoline, ethylene, and polyvinyl-chloride (see Figures E-12, E-13 and E-14. While it is not possible to unequivocally state that the methanation of urban waste will follow similar curves (In fact, W.M.I. personnel expressed the opinion that learning-experience curve behavior would not be followed), it is possible to encourage this phenomenon through careful structuring of contract arrangements. In particular, it must be realized that the full service contractor will probably use some postulated learning-experience rate in calculating his operating costs and margin. Recognition of the existence of this behavior will enable the responsible parties

Source: Reference 4, p. 129

FIGURE E-8. PERFORMANCE OF AN INDIVIDUAL FLUID CATALYTIC CRACKING UNIT

Source: Reference 4, p. 130

FIGURE E-9. PLOT OF PERFORMANCE CORRESPONDING TO FIGURE E-8.

Source: Reference 4, p. 130

FIGURE E-10. PRODUCTIVE REFINERY LABOR MAN-HOURS FOR MAINTENANCE AND SHUTDOWNS

Source: Carl A. Bennett, Application of a Learning Curve to a Maintenance Problem, Second Annual Quality Control Symposium of the Dallas-Fort Worth Section, ASQC, March 16, 1957.

Source: Reference 4, p. 131

FIGURE E-11. MAINTENANCE LEARNING CURVE AT A GENERAL ELECTRIC PLANT

* In constant (1958) dollars (excluding California).

Source: Perspectives on Experience, Boston Consulting Group, 1972.

FIGURE E-12. PRICING HISTORY OF U.S. PRODUCED MOTOR GASOLINE

Source: Perspectives on Experience, Boston Consulting Group, 1972

FIGURE E-13. PRICING HISTORY OF ETHYLENE

Source: Perspectives on Experience, Boston Consulting Group, 1972

FIGURE E-14. PRICING HISTORY OF POLYVINYLCHLORIDE

to tailor a full-service contract that encourages minimum cost operation of the facility, resulting in minimum cost to the municipality. Cost minimization incentives might include contract clauses such as allowing the contractor to retain a certain percentage of decreased cost, municipal financing for process and equipment improvements, tax incentives linked to cost performance, or encouraging non-restrictive labor agreements.

6.2 SELECTION OF LEARNING-EXPERIENCE CURVES

Selection of learning-experience curves for use in the risk analysis was not simple. Each historical curve represents the interaction of an individual product with a dynamic market. (See Figures E-12, E-13 and E-14.) Given the unique nature of each product-market set, it is difficult to construct an overall learning-experience curve for the anaerobic digestion process. However, evidence presented throughout the literature strongly suggests that labor and maintenance expenses are likely to follow a learning-experience curve. Therefore, learning-experience curves with slopes of 70% and 90% were used for maintenance cost per unit (ton of waste handled) and labor cost per unit (Figures E-15 and E-16). Values were extracted from these curves, corrected for inflation, and input to the risk model.

6.3 IMPACT OF LEARNING-EXPERIENCE CURVES IN RISK ANALYSIS

The potential impact of learning-experience curves on venture financial outcome is displayed in Table E-5. It can be seen that a significant improvement in the financial outcome of the project results from the application of learning-experience curves to the maintenance expense. The results of this analysis indicate that in the determination of Federal policy relative to waste to energy technologies, the effects of learning-experience curve behavior on financial performance

FIGURE E-15. ASSUMED LEARNING - EXPERIENCE CURVE FOR MAINTENANCE COST

FIGURE E-16. ASSUMED LEARNING - EXPERIENCE CURVE FOR LABOR

TABLE E-5. LEARNING-EXPERIENCE CURVE ANALYSIS RESULTS

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Section	Policy Variable Considered	Δ Policy Variable Base Case	Possible Fed. Policy Option	Impact on Venture											
				Present Worth				Median Pay-back Period	Present Worth-Energy Savings						
				Discount Rate(%):					Discount Rate(%):						
					2	6	8		10		2	6	8	10	
9	Maintenance Cost	70% Learning-Experience Curve	Base Case	Avg. (\$1000)	67293	14995	-208	-10970	Quarter 4	Avg. (\$1000)	17563	11374	9322	7726	
				σ (\$1000)	7975	5185	4377	3791	Year 15	σ (\$1000)	221	166	148	133	
		90% Learning-Experience Curve	Encourage Innovative Municipal Contracting Procedures	Avg. σ	97719	33374	14327	654	Quarter 1	Avg. σ	17563	11374	9322	7726	
					7864	5083	4284	3706	Year 14		221	166	148	133	
	9	Labor Cost	70% Learning-Experience Curve	Tax Incentives Linked to Cost Performance	Avg. σ	80211	22711	5858	-6147	Quarter 1	Avg. σ	17563	11374	9322	7726
						7921	5138	4335	3753	Year 15		221	166	148	133
9	Labor Cost	50% Learning-Experience Curve	Encourage Innovative Municipal Contracting Procedures	Avg. σ	71492	17534	1800	-9362	Quarter 3	Avg. σ	17563	11374	9322	7726	
					7935	5155	4351	3769	Year 15		221	166	148	133	
DYNA			Tax Incentives Linked to Cost Performance	Avg. σ	69111	16082	646	-10290	Quarter 4	Avg. σ	17563	11374	9322	7726	
					7958	5172	4367	3782	Year 15		221	166	148	133	

should be carefully considered. In addition, policies designed to encourage this type of behavior from project participants should be pursued.

CHAPTER 7
POTENTIAL FEDERAL POLICY OPTIONS AND STRATEGIES

Costs associated with the construction of an energy recovery facility are beyond the financial resources of most municipalities. For example, design and construction costs associated with enlarging the Pompano Beach facility to a 1,000 ton per day capacity plant are estimated by W.M.I. to be approximately \$50 million. It was estimated that this cost could increase to as much as \$75 million if construction delays or other potential impediments occur. This level of debt is greater than the total bonded indebtedness of many local governments. As an example, the bonded indebtedness of Pompano Beach, Florida is presented in Table E-6.

TABLE E-6
BONDED DEBT, 1977
POMPAÑO BEACH, FLORIDA

	OUTSTANDING (\$1000)
WATER REVENUE	3,934
PUBLIC IMPROVEMENTS	460
SEWER REVENUE	10,398
CIGARETTE TAX	1,150

SOURCE: Moody's Municipal & Government Manual, 1978.

Even if regional or special state authorities are established to raise the necessary capital, some form of Federal assistance may be required.

Potential Federal policies to support commercialization of energy recovery systems have been suggested in several DOE sponsored studies (Reference 1). Those suggestions reflect risk perspectives of potential project participants and, therefore,

form the basis for policy options presented here. The intent of this chapter is to present Federal policy options potentially applicable to the 1,000 ton per day anaerobic digestion plant.

7.1 LOAN GUARANTEE PROGRAM

Most capital expenditures made by municipalities are financed by two types of bonds: general obligation and revenue. General obligation bonds are backed by a claim on the local tax base and are usually employed for facilities which do not generate revenue or serve all members of the community. Historically, these bonds have been viewed as relatively safe investments with low risk levels. However, as more urban areas experience financial problems, bond ratings are being downgraded by major investment service firms. The reluctance of voters to approve sales of general obligation bonds further constrains their use. In addition to these considerations, the use of general obligation bonds backed by Federal loan guarantees is not viewed as a viable policy option primarily because the government's intention would be to support only the particular project under consideration so that commercialization would be fostered. Revenue bonds are more appropriate for this purpose

Revenue bonds are issued against expected receipts from the operation of a proposed facility, but (Reference 5), "...since they [revenue bonds] are not backed by an all inclusive pledge of general taxing powers - are usually considered to be somewhat riskier than general obligations and accordingly, sell for higher interest rates." In spite of these higher interest rates, the total cost of capital to the municipality from the issue of revenue bonds is still lower than that available to private firms because the bond interest is usually tax exempt. Figure E-17 portrays municipal and corporate bond yields. The 2% difference between corporate and municipal bond yields represents investor perceived benefits of tax exempt income.

Note: Reoffering yields are annual averages of monthly data on 20-year bonds.
Moody's Ratings and Services.

Source: Twentieth Century Fund, The Rating Game

FIGURE E-17. YIELDS OF PRIME MUNICIPAL AND CORPORATE BONDS (Aaa GRADE), 1950-1972).

Due to the uncertainties associated with a new technology, revenue bonds for a 1,000 ton per day energy recovery facility without Federal assistance or backing would probably have higher than normal interest rates. For the same reason, the issuance of revenue bonds would most likely require a much more detailed financial prospectus than normally provided by a municipality, with greater description of risks and return. In addition, guarantee of repayment through use of restrictive covenants, such as guaranteed sales of products at a fixed price, may be required in order to be attractive to investors. DOE has proposed use of loan guarantees to encourage the construction of demonstration facilities that convert urban wastes into forms of energy such as steam, methane gas, chemical feedstocks, and alcohol fuels. The regulations would limit federal guarantees to 75% of a facility's total cost or 90% of construction and start-up costs (Reference 6). Further, guarantees over \$50 million require Congressional approval. Bonds backed by a Federal loan guarantee would probably be issued with a higher interest rate than the municipality's average rate since interest earnings would be taxable. However, the municipality would be refunded the interest rate differential between the rates charged for tax exempt bonds and taxable bonds (Reference 1). Base case risk profiles of cash flow and before-tax profit can support implementation of a loan guarantee program in certain situations where private sector funding is not available at acceptable rates.

During the initial three years of the venture, a negative cash flow is experienced since no revenues are realized during planning, design, and construction phases. The cash flow turns positive in year four when revenues from the tipping fee and sales of methane and CO₂ begin. If the government were to guarantee the maximum permissible amount allowed by law, the municipality would be independently responsible for only \$12.5 million in capital expenditures of \$50 million estimated cost. Bonds issued against this amount and structured with a short

maturity period of 5-10 years could enable a municipality to demonstrate the viability of the investment to the capital market during the early years of operation. Additionally, phased maturities for Federally guaranteed bonds could also enable the municipality to exhibit their ability to meet these obligations.

Even under low levels of risk (80% and 100% chance of exceeding the indicated profit), the before-tax profit risk profile (Figure E-4) indicates that revenues will support a debt service program at an accelerated rate compared to the straight time amortization used in the model. The venture's mean rate of return is approximately 7%, which is consistent with the recent average cost of capital to municipalities.

The tax exempt status of most municipal revenue bonds is particularly attractive to three sources of capital: individuals, banks, and fire and casualty insurance companies. Foremost among these sources at this time are commercial banks. Commercial banks are subject to the full marginal income tax rate, which causes them to invest in tax exempt bonds to improve their profit picture. As shown in Table E-7, drawn from the Twentieth Century Fund's The Rating Game, commercial banks in 1970 held 48% of all state and local securities. Therefore, they would probably be the primary market for the sale of tax exempt revenue bonds. The International City Management Association (ICMA) recommends that municipalities attempting to attract investments from commercial banks provide the banks with complete and accurate financial data on the venture. Expense and revenue projections, cash flow streams, and management policies are the most vital components of these data. In addition, financial projections relative to the project uncertainties are valuable. This information will be used in conjunction with the municipality's current bond rating to reach an investment decision.

Federal policy should encourage municipalities to finance as much of the facility's cost as possible with tax exempt revenue bonds. Federal loan guarantees would then be employed only in situations where private sector project financing was not possible.

TABLE E-7. OWNERSHIP OF STATE AND LOCAL SECURITIES, 1950-1970
(Billions of Dollars)

Investor Group	1950		1960		1970	
	Dollar Amount	Percent of Total	Dollar Amount	Percent of Total	Dollar Amount	Percent of Total
Banks	8.2	32.6	17.7	25.0	70.2	48.0
Individuals	10.0	39.6	30.8	43.5	47.4	32.5
Fire & Casualty						
Ins. Cos.	1.1	4.4	8.1	11.5	17.8	12.2
Others	5.9	23.4	14.2	20.0	10.8	7.3
TOTAL	25.2	100.0%	70.8	100.0%	146.2	100.0%

SOURCE: Federal Reserve Board, Flow of Funds.

7.2 LOANS

Consistent with prior DOE policy, an intensive loan program to support commercialization of a 1,000 ton per day anaerobic digestion facility does not appear warranted based on base case risk profiles. Both the NPV and IRR indicate that the facility could be financed at recent costs of capital.

7.3 OTHER FEDERAL GUARANTEES

The base case was modelled under the assumption that the tipping fee would be sufficient to cover operating expenses and debt service. However, the resulting tipping fee level may be an inhibiting factor to ultimate adoption of the technology. Government analysts must consider policy options available to them to circumvent this barrier. Besides use of direct subsidies, various Federal guarantees could lower project uncertainty and increase expected return.

Revenue guarantees would provide a type of financial umbrella for the venture. In essence, this type of guarantee would insure the project against unfavorable variances in quantities of products recovered, quality of products, quantities of products actually purchased, and prices received. However, this policy would be extremely difficult to effectively implement due to the resulting reduction in incentive for parties to operate efficiently. Particular care would have to be taken to ensure that prices for recovered products reflected their true market value.

Price guarantees are a subset of revenue guarantees, namely guarantees related to any unfavorable variance in the price received for recovered products. No Federal guarantee would be attached to product quality or quantity, or quantity sold. Once again, attention would have to be devoted to ensuring that prices offered for recovered products reflected their true market value.

Market guarantees generally refer to a purchase commitment for a specified product at a full and fair economic value for a specified period of time. This type of agreement has been used, without Federal guarantees, in several existing urban waste energy recovery facilities. From preliminary contacts

made during the conduct of this case study, the private sector appears to be amenable to guaranteeing markets for process end-products.

7.4 FEDERAL ASSISTANCE IN PROJECT IMPLEMENTATION

Often, municipalities experience great difficulty during initial phases of project implementation -- particularly in planning, system selection, and system procurement. Costs associated with preliminary engineering, legal, and financial advisory services place a heavy burden on municipal resources. Local operating budgets are not usually designed to cover these expenditures. It should be noted that during discussions with W.M.I., the need for this type of assistance to municipalities was stressed.

7.5 ADDITIONAL FEDERAL STRATEGIES

Municipal ownership of the facility may compound the complexity of barriers to commercialization. Because of the financial problems experienced in many urban areas, especially in certain areas of the East Coast where this technology has the greatest potential, DOE/BCS may elect to fund one or more demonstrations under which ownership would be vested in an independent authority. This arrangement has been used successfully in other public projects for water and sewer systems and public transit.

Federal attention must also be devoted to resolving coordination issues between the Federal government, private industry, and state and local governmental units. Careful consideration must be given to issues of waste flow control and regulatory oversight.

CHAPTER 8

IMPACT OF FEDERAL STRATEGIES ON RISK ANALYSIS RESULTS

Table E-8 presents the quantified impact of several possible Federal policy options on the financial outcome of the venture. The policy options considered include:

- o Increased Federal RD&D Funding
- o Tipping Fee Price Guarantee
- o Feedstock Quantity Guarantee
- o Methane Price Guarantee
- o Methane Market Guarantee
- o Federal Planning Assistance

Once again, the importance of policy options affecting the tipping fee price and feedstock quantity stands out because of the magnitude of their impacts on the venture. Guaranteeing a tipping fee price at the minimum level used in the calculations (see Table E-1) would have a significant negative impact on the venture - decreasing the rate of return to approximately the 2 percent level; while guaranteeing the tipping fee at the level used as the most likely fee raised the internal rate of return to approximately 8 percent.

Federal programs designed to advance the start of sales of products from the venture have a significant potential for improving the financial results of the venture. Possible strategies to accomplish this involve accelerating the commercialization schedule by: increasing Federal RD&D funding; improving the financial aspects of the venture so that the private sector will risk its own capital rather than incur delay while awaiting Federal action; coordinating Federal regulatory actions to expedite construction, etc.

Decreasing the financial burden faced by a municipal entity planning a 1000 ton per day anaerobic digestion facility also

TABLE E-8. POLICY ANALYSIS RESULTS

DYNATREND

Section	Policy Variable Considered	Δ Policy Variable Base Case	Possible Fed. Policy Option	Impact on Venture										
				Present Worth				Median Pay-back Period	Present Worth-Energy Savings					
				Discount Rate(%):					Discount Rate(%):					
					2	6	8	10		2	6	8	10	
			Base Case	Avg. (\$1000) σ (\$1000)	67293 7975	14995 5185	-208 4377	-10970 3791	Quarter 4 Year 15	Avg. (\$1000) σ (\$1000)	17563 221	11374 166	9322 148	7726 133
1	Max. Delay Start Sales	½ Year Added Delay		Avg. σ	62326 9186	12351 5759	-2005 4721	-12066 3977	Quarter 3 Year 16	Avg. σ	17323 325	11165 264	9126 241	7543 222
1	Min. Delay Start Sales	Possible One Year Advance	Increase Federal RD&D Funding-Decrease Venture Uncertainty	Avg. σ	73988 14116	19600 8744	3687 6964	-7639 5578	Quarter 2 Year 15	Avg. σ	17605 334	11410 277	9356 225	7758 236
5	Tipping Fee Price	Min. Price Deterministic	Federal Price Guarantee	Avg. σ	6124 3345	-23615 2406	-31479 2164	-36598 1864	No Pay-back Period	Avg. σ	17530 240	11352 170	9303 147	7710 130
		Most Likely Price Deterministic	Federal Price Guarantee	Avg. σ	73061 4190	18624 2939	2725 2589	-8568 2337	Quarter 3 Year 15	Avg. σ	17533 240	11353 170	9304 147	7711 130
5	Tipping Fee Units	Min. Units Deterministic	Federal Waste Flow Control.Federal Tipping Fee Subsidy	Avg. σ	48751 8139	3401 5231	-9559 4368	-18606 3738	Quarter 3 Year 17	Avg. σ	16165 124	10465 103	8576 96	7106 89
		Most Likely Units Deterministic	Federal Waste Flow Control.Federal Tipping Fee Subsidy	Avg. σ	60459 8526	10778 5454	-3589 4543	-13714 3877	Quarter 3 Year 16	Avg. σ	17098 130	11069 109	9070 101	7516 94

has a positive impact on the venture. By decreasing the first year capital expenditure by 50 percent, the average rate of return from the venture is increased to approximately 9 percent.

The policy options considered were designed to demonstrate the ability of a computerized risk analysis model in the areas of policy analysis and policy formulation. It must be remembered that the present case study considered the venture from the perspective of a municipality. Consideration of the venture from a private sector perspective offers a much wider range of potential policy options. An example of private sector policy analysis is presented in Appendix D of this report, Gas-Fired Heat Pump Case Study.

CHAPTER 9

CONCLUSIONS

The risk analysis case study of a hypothetical 1000 ton per day anaerobic digestion facility owned by a local government entity and operated by a full-service contractor provided insight into a number of policy related questions. After allowing for the subjective uncertainty of expert judgement with respect to costs and predictions of future prices, the venture appeared to be financially viable. However, one must qualify this statement in light of the following facts:

- o Many municipalities will require financial assistance during the project planning stages.
- o The approximately 7 percent internal rate of return generated by the venture, after meeting its debt expense, may have to be scaled down in order for the facility to be economically competitive during its first few years. To become competitive, the tipping fee (calculated to meet operating and debt expenses) may have to be reduced from the values used. Profits generated by the sale of methane and carbon dioxide could be channeled into reducing this fee.
- o A supply of waste must be guaranteed. Legal judgments with regard to municipal waste control and supply could impose significant barriers to adoption of the technology.
- o Markets must be guaranteed for the process by-products in order to allow for a competitive tipping fee.
- o The environmental ramifications of the technology must be clarified before the technology can be marketed.

Several possible Federal policy options were discussed in the previous chapters of this report. The most appropriate strategies appear to center around the following concepts:

- o Federal guaranteed loans
- o Federal market guarantees
- o Federal planning assistance
- o Federal regulatory coordination
- o Federal market guarantees

It must be stressed that time did not allow for an exhaustive consideration of all policy options. The many possible options available to encourage private sector participation were not considered within the current case study. Both of these areas should be considered in any future case study enhancements.

One area which must be recognized in formulating any coherent policy involves the impact of possible learning-experience curve behavior of the financial outcome of the venture. Various learning-experience curve slopes were assumed in the analysis for maintenance cost and labor expense, resulting in significant financial impacts on the venture. Contracting arrangements must recognize the possibility of such behavior and should encourage it to the maximum extent.

CHAPTER 10
REFERENCES

1. "Federal Assistance by the Department of Energy in the Demonstration of Energy and Materials Recovery Systems," First Draft-Revised, 1 August 1978.
2. "Scaling Up Coal Liquids," Combustion, April 1979, p. 39.
3. "Draft, Commercialization Strategy Report," submitted by the Urban Waste Technology Commercialization Task Force, August 31, 1978, p. 16.
4. Hirschman, Winfred B., "Profit from the Learning Curve," Harvard Business Review, January-February 1964.
5. Twentieth Century Fund, The Rating Game, p. 3.
6. "Federal Price Support Program for Municipal Waste Reprocessing Demonstration Facilities," Federal Register Vol. 44, No. 175, September 7, 1979, p. 52643.

ATTACHMENT 1
MINUTES OF MEETING WITH
WASTE MANAGEMENT INCORPORATED
2/28/79

Location - Oak Brook, Illinois

Participants - Waste Management, Inc. - Peter Ware

John Williams

Bill Marra

Dynatrend, Inc.

- Robert Care

Alan Fleischman

Past Studies Related to Commercialization

- o No internal venture analysis has been done for 1,000 ton per day REFCOM facility.
- o Any project is highly site dependent.
- o Local political climate often has a major impact on waste disposal/conversion facilities.
- o REFCOM facility typically situated in area where landfill capacity is diminishing and near existing gas transmission lines. East Coast appears particularly suited to concept.

Present State of Technology Related to Commercialization

- o Technology is well demonstrated - now a question of optimizing process.
- o W.M.I. perceives plant as being owned by local government entity or possibly long-term leased to community (Third Party Ownership). Franchise possibility.
- o W.M.I.'s corporate philosophy = promote itself as a full service contractor - use management and engineering expertise to design, build and operate plants. Not interested in ownership or the assumption of profit risk -willing to accept operating risk over 20 year period. Does not want the capital investment appearing on its balance sheet.

- o Technologically REFCOM is not an efficient means of producing energy - vis a vis competing technologies (RDF, mass burning, modular incinerators) Energy efficiency $\cong 30\%$.
- o Deregulation of natural gas pricing perceived as being critical to market acceptance - opening new market opportunities.
- o Price of CO₂ also important to eventual acceptance - becoming a desirable product.
- o W.M.I. sees the municipal - local sector as the focal point for any Federal assistance programs.
- o Chief Federal role in the following areas: (1) Research into environmental and health aspects of technology, (2) provide grants to local sector to promote technology, and (3) education of public sector-effective dissemination of information.
- o W.M.I. stated that REFCOM would have gone ahead w/o government involvement - it was already aligned with Allis Chalmers in a similar project.
- o Private venture vs. Private/Federal venture - if technology is patentable industry would avoid government participation because of (1) information disclosure laws, (2) necessity of small business set asides, and (3) cost of audits.
- o Primary benefit of government participation in Pompano Beach has been to improve the respectability of the waste management industry.
- o W.M.I. opposes any attempt to legislate waste flow control. Proposes possible use of federal subsidies to REFCOM facilities until effective tipping fee becomes competitive with competing landfills.

Waste Management Data for 1,000 Ton Per Day Scaleup of Pompano Beach

1. Earliest possible date for production and sales of gas from facility - 1985.

2. Cost to design and construct plant - \$50 million. Range = \$45-\$75 million. This cost includes land, front end, gas purification facility, construction supervision, start up, etc.

Capital Cost Breakdown - (\$ 1979)

	<u>Range</u>	
7% Engineering	5 - 10%	1st year
3% Construction Supervision	3 - 5	
10% Contingency for Delays	8 - 12	40% 2nd year
10% Miscellaneous Services	5 - 10	60% 3rd year
7% Construction Financing	6 - 8	
30% Materials	27 - 33	
33% Construction Cost	27 - 39	

3. Annual Operating and Maintenance Costs (\$ 1985)

Maintenance - 4½% - 5% of capital

Labor - \$400,000 (13 people ± 3 @ \$25,000 per year)

Utilities - \$1 million - (Range \$300,000 - \$1.2 million - chiefly electricity)

- Consumes 12% of gas produced (Range 10 - 15%)

- Gas produced at rate of 6,000 ft³ per ton - 50% methane, 50% CO₂ (present price \$.22 per ft³)

Disposal Charge - \$12/ton ± \$2 (400 tons/day ± 50 tons)

G&A - 1% of above

Tipping Fee - adjusted up or down to arrive at 20%

pre-tax profit for full service contractor

4. Escalation Rates - 7% per year except for utilities -11% per year.
5. No learning curve expected in O&M costs over 20 year period - because of obsolescence of equipment and wearout.

6. Cost-volume-profit analysis - would require a throughput agreement to protect operator from supply interruption.
No major change in costs with volume change.
7. Profit picture - engineering design and construction -1% of capital cost - \$500,000.
 - 2nd year - 40% \$200,000
 - 3rd year - 60% \$300,000
 - 4th year - 20% pre-tax profit on services
8. Contract may have revenue sharing clause for price increases in gas produced.