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ECONOMICS OF NONMETROPOLITAN SOLID WASTE RESOURCE RECOVERY: A CASE STUDY AND SOME EXTENSIONS 1/

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Introduction

The utilization of land as a depository for man-made waste is of concern to many persons because of its potential contribution to environmental decay and the loss of valuable (particularly non-renewable) resources. The negative impacts attributed to land disposal of solid waste--landfilling--include water pollution by landfill leachate, blowing of paper and general unsightliness, creation of methane gas and odors, and loss of recoverable materials and energy. These problems are accentuated by the increasing volume of solid waste generated [4,12] and the decrease in land available for disposal sites. Because of developments in the field of resource recovery, there is in the solid waste dilemma considerable opportunity for meeting the problems of waste management and energy scarcity at the local level.

An increasingly attractive process for the partial resolution of these problems appears to be the utilization of solid waste as a supplementary fuel in electric plant boilers. The potential benefits of this process include: less burning of coal (or other fuels) with resultant savings in coal purchases, less need for landfill space, recovery of materials (e.g., ferrous metals) from the refuse stream, and opportunity for a public or private utility to aid a community in resolving its solid waste management problem.

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Although generally viewed as a desirable goal, the institution of resource recovery systems has been limited to large urban areas. Materials recovery alone was (and is) economically viable only in high waste generation areas; even in these locations, processing refuse to recover materials is economical only when supported by revenues from user fees as well as from the sale of recovered materials [1]. However, the recovery of energy resources as well as materials from solid waste has increased the economic feasibility of recovery systems for a wide range of communities of varying size and location.

The key feasibility factor in this regard is that of existing power plant facilities capable of burning processed refuse in the power-generation process. These facilities are crucial in two respects:

(1) By burning refuse in an existing plant, the process utilizes an established system for producing and distributing electricity. Existing boilers or new units designed to burn solid waste may be used; the energy recovered from the refuse is thereby assured a market.

(2) The use of existing facilities minimizes investment in plant and equipment. Huge expenditures for the construction of new plants are not necessitated.

The importance of energy recovery often supersedes materials recovery; in fact, "resource recovery is economically viable provided that the community has an electric utility which can utilize the organic fraction" [1]. A study by Midwest Research Institute [11] determined that the capital investment requirements for fuel recovery were lower than any other recovery process investigated. The study further concluded that "the fuel recovery concept has the most favorable overall economics of any investigated".

The scale requirements normally associated with resource recovery are substantially reduced in those systems including the recovery of energy from refuse.

Scale economics are further reduced by the commercial availability of systems designed specifically for relatively small communities. The resource recovery plant in Ames, Iowa, which serves a county population of approximately 60,000, is an example of a small scale application. According to data from the National Coal Association and a national survey funded by the U.S. Environmental Protection Agency, there are approximately 300 coal burning steam electric generating plants similar to the Ames plant located in the nonmetropolitan areas of the United States [16,19].

Recent increases in the costs of conventional fossil fuels (coal, oil, natural gas) create the greatest incentive for energy and materials recovery systems. Many indicators suggest a sizeable increase in future demand for coal, as the electric power industry is likely to increasingly rely on coal and its derivatives. This demand is likely to be accentuated in those areas most susceptible to natural gas shortages, i.e., the Midwest, Northeast and Mid-Atlantic states. Problems in nuclear power development, refinements in coal gasification technology, and projected absolute increases in energy demand all point to increasing demand for coal (with resultant price increases). Increases in the price of coal and other energy sources will tend to make solid waste an attractive energy source.

The following case study analysis focuses on a coal burning steam electric municipal power plant located in a nonmetropolitan county in Northeast Ohio. The specific objectives of the analysis were: (1) to ascertain the technical feasibility of converting the existing power plant facility to include an energy recovery system, (2) to complete a benefit-cost sensitivity analysis of the proposed resource recovery prototype to evaluate the technical and economic parameters of importance to resource recovery in a nonmetropolitan location, and (3) to determine the potential net reduction in external impacts from implementation of such a system.

The Study Area

The area which provides the focus for this analysis is Wayne County, Ohio. Located in the northeastern quadrant of the state, Wayne County has a population of approximately 87,000. Like many other areas, Wayne County is rapidly exhausting its present landfill space. In addition, these current sites are considered suspect in terms damage to surface and groundwater supplies, negative aesthetic impacts, and generally poor management techniques. Because the county is a leading agricultural area of the state, the cost of land for disposal sites is high. Residents in the county's population centers oppose the development of new landfills in any areas close to the waste-generation centers (generally, their residences).

The city of Orrville located in Northeast Wayne County owns and operates a 75-megawatt municipal electric plant which appears to be a promising site for an energy and materials recovery system similar to that in Ames, Iowa. Two of the four boilers of Orrville Municipal Power (OMP) are side-fired pulverized coal units of modern design which have the potential to burn refuse in combustion with coal. Depending upon the refuse-to-coal firing ratio utilized (15:85, 20:80 or 25:75), OMP may fire from 51 to 84 percent of the solid waste now generated in Wayne County.

The prototype recovery system would include a horizontal hammermill to reduce incoming refuse to optimum combustion size, an air classification process (zig-zag columnar or elutriative) to separate the refuse into combustible and noncombustible fractions, a magnetic system to recover ferrous scrap material for sale, processed refuse storage facilities, and refuse-fuel transport and firing mechanisms. The entire system (refuse input and processing) would operate in an enclosed building adjacent to the electric power plant.

Methodology

The methodology used to evaluate the prototype resource recovery facility is a standard benefit-cost sensitivity approach. Low,medium ("most likely outcome") and high estimates are made for key technical and economic parameters to determine their relative impacts on economic outcome. Although difficult to forecast, the direct benefits of resource recovery appear to include the cost savings of reduced landfill activity and extension of the lives of existing sites, savings from reduced dependence on conventional fuels, and revenues from the sale of recovered materials. Indirect benefits may include reduced consumption of virgin materials and of the resources required to produce and transport them, reduced landfill-created water pollution and better air quality due to the use of low-sulfur refuse as fuel.

Four benefit-cost criteria are used to evaluate the prototype: benefit-cost ratio, net benefits, internal rate of return and pay-out period. Determination of the benefit-cost ratio follows the pattern of Seneca and Taussig [13] which is similar to that of Eckstein [6] and Howe [9]:

$$B/C = \frac{\sum_{t=1}^{T} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{T} \left[\frac{O_t}{(1+i)^t} \right] + K}$$

where: B = annual benefits resulting from project

O = recurring costs, or annual operating and maintenance expenses incurred

T = time period over which benefits and costs occur

i = discount rate

K = capital outlays incurred in the initial year of the project.

The net benefit criteria provides another measure of the economic feasibility of a given investment. This criterion is derived as follows:

$$\text{Net Benefits} = \sum_{t=1}^{T} \frac{B}{(1 + i)^t} - \left[\sum_{t-1}^{T} \frac{0}{(1 + i)^t} + K \right]$$

Internal rate of return and pay-out period are other frequently used benefit-cost criteria used in the analysis of this case study. Internal rate of return is that rate of discount which makes the discounted present value of net benefits equal to the value of the initial outlay. Investments are considered justified if the internal rate of return exceeds that generated in the best alternative use of resources or exceeds some other predetermined rate. In its simplest form, internal rate of return is that r for which:

$$\sum_{t=1}^{T} \frac{(B_t - 0_t)}{(1 + r)^t} = K$$

The pay-out period criterion measures the number of time periods (usually years) necessary to recoup the initial outlay. This criterion is calculated by summing the values of discounted net benefits for consecutive periods until the value of the initial capital outlay has been reached.

The discount rate chosen for use in the methodology is recognized to be crucial to the outcome of the analysis. The rate indicates if capital provided for any particular project yields as high an economic return as it would among alternative uses. The choice of a discount rate also involves social value judgements about benefits and costs which may accrue to future generations.

To minimize subjective argument concerning the validity of using a particular rate of discount, three rates are utilized in the analysis--5, 9, and 11 percent. This action reflects the use of alternative (low, medium and high) values for the key technical and economic parameters judged crucial to the resource recovery prototype. The key technical parameter involved is the refuse-to-coal firing ratio utilized in the combustion process. This ratio determines how much refuse can be fired in the boilers, thereby dictating the processing capacity required in the recovery system. The primary economic parameters are: the projected annual coal price increase, rate of discount, and net ferrous revenue per ton of recovered metal scrap. Initial capital investment, a final parameter, tends to have technical as well as economic dimensions. Table 1 presents these parameters and the values used to demonstrate the sensitivity of the system.

There is some supporting evidence for the parameter projections used, particularly for the medium values, from previous research, historical data, consultation with authorities in the various areas, etc. However, the evidence is not sufficient to assign probabilities to the array of possible values for each parameter. Variations in all parameters may occur, but the medium parameter estimates are assumed to represent the "most likely outcomes".

Nine benefit streams are derived by combining each of the three refuse-to-coal firing ratios with low, medium and high coal price increases and net ferrous revenue schedules. Additional benefits are the elimination of the costs associated with a landfill large enough to accept all of the county's waste and elimination of transport costs incurred in delivery of all the county's waste to a centrally-located landfill. Each benefit-stream is then discounted at 5, 9, and 11 percent.

Costs measured in the analysis are: operating costs of the resource recovery prototype, operating costs of a small scale landfill suitable to accommodate that waste not processed plus residuals material from the recovery system, transport costs for refuse delivered to the recovery facility, and transport costs for that refuse taken to the small landfill. Each cost stream is then discounted at 5, 9, and 11 percent. The individual components of benefits and costs, such as labor, maintenance materials, petroleum fuels for waste transport, utilities, insurance, plant and equipment, etc., are derived from

TABLE 1

SUMMARY OF LOW, MEDIUM AND HIGH ESTIMATES
FOR TECHNICAL AND ECONOMIC PARAMETERS

Factor	Parameter Projection Estimate		
	Low	Medium	High
refuse:coal firing ratio	15:85	20:80	25:75
annual coal price increase	1975-80:10% 1981-94: 4%	1975-80:12.5% 1981-94: 7%	1975-80:17% 1981-94: 8%
discount rate	5%	9%	11%
initial investment	$3,284,081	$4,105,101	$5,131,376
net ferrous revenue/ton	$15.00	$22.00	$29.00

manufacturers and engineers estimates [14, 15] and data from previous resource recovery studies [2,3,7,17]. These components are projected for a recovery system plant life of 20 years. Inflationary effects are incorporated into the analysis based on performance data relevant to each cost or benefit component over the past 20 year period, 1955-1974 [5].

Analysis Results

Results of the benefit-cost ratio and net benefit analysis are presented in Tables 2, 3, and 4 given successive increase in the initial capital investment estimate (K). The data in Tables 2, 3, and 4 indicate the relative impacts of the alternative technical and economic parameter values upon the B/C and B-C economic criteria. For example, given medium values for all parameters, increases in the firing ratio from 15:85 to 20:80 and from 20:80 to 25:75 increases net benefits by $2.758 million and $2.868 million, respectively. Examination of the other data permits the determination of the relative effects of the range in values of the individual technical and economic parameters on economic feasibility.

Analysis of the resource recovery prototype by the medium estimates represents the "most likely outcome". While somewhat arbitrary, the evidence gathered indicates that the medium parameter projections represent the most plausible values. Analysis of the most likely outcome situation by the four benefit-cost criteria yields the following results:

1) benefit-cost ratio = 1.35
2) net benefits = $3,816,000
3) pay-out period = 10.7 years
4) internal rate of return = 17.9 percent

These data suggest that the prototype is an acceptable use of resources, as its benefit-cost ratio is well in excess of unity, it provides substantial

TABLE 2

B/C AND B-C ANALYSIS OF RESOURCE RECOVERY PROTOTYPE BY FIRING RATIO AND ALTERNATIVE PARAMETER PROJECTION

K = $3,284,081

Firing Ratio Parameter Projection	Discount Rate 5 % B/C	B-C*	9 % B/C	B-C*	11 % B/C	B-C*
15:85						
Low	1.16	2,118	1.02	196	.95	(450)
Medium	1.37	4,879	1.18	1,878	1.20	889
High	1.61	8,000	1.38	3,831	1.27	2,465
20:80						
Low	1.40	5,142	1.24	2,396	1.16	1,422
Medium	1.75	9,492	1.46	4,637	1.35	3,208
High	2.03	13,121	1.73	7,241	1.59	5,307
25:75						
Low	1.70	8,627	1.49	4,702	1.38	3,374
Medium	2.08	13,230	1.78	7,505	1.64	5,606
High	2.50	18,432	2.11	10,761	1.94	8,233

*Thousands of dollars.

Source: Original data.

TABLE 3

B/C AND B-C ANALYSIS OF RESOURCE RECOVERY PROTOTYPE BY FIRING RATIO AND ALTERNATIVE PARAMETER PROJECTION
K= $4,105,101

Firing Ratio Parameter Projection	5 % B/C	5 % B-C*	9 % B/C	9 % B-C*	11 % B/C	11 % B-C*
15:85						
Low	1.09	1,194	.94	(728)	.87	(1,374)
Medium	1.29	3,955	1.10	955	1.01	(33)
High	1.52	7,076	1.27	2,967	1.16	1,541
20:80						
Low	1.32	4,218	1.15	1,472	1.06	498
Medium	1.64	8,568	1.35	3,713	1.24	2,284
High	1.91	12,197	1.59	6,317	1.45	4,383
25:75						
Low	1.60	7,703	1.37	3,778	1.27	2,450
Medium	1.95	12,306	1.64	6,581	1.50	4,682
High	2.34	17,506	1.95	9,837	1.77	7,309

*Thousands of dollars.

Source: Original data.

TABLE 4

B/C AND B-C ANALYSIS OF RESOURCE RECOVERY PROTOTYPE BY FIRING RATIO AND ALTERNATIVE PARAMETER PROJECTION

K = $5,131,376

Firing Ratio Parameter Projection	Discount Rate 5 % B/C	B-C*	9 % B/C	B-C*	11 % B/C	B-C*
15:85						
Low	1.02	271	.86	(1,652)	.79	(2,297)
Medium	1.20	3,032	1.00	31	.91	(958)
High	1.41	6,152	1.16	1,984	1.06	618
20:80						
Low	1.23	3,295	1.05	549	.96	426
Medium	1.52	7,644	1.24	2,790	1.12	1,360
High	1.77	11,273	1.46	5,394	1.32	3,460
25:75						
Low	1.48	6,780	1.25	2,855	1.14	1,527
Medium	1.81	11,383	1.49	5,658	1.35	3,759
High	2.17	16,584	1.77	8,914	1.60	6,386

*Thousands of dollars

Source: Original data.

positive net benefits, it will recover the initial investment in slightly over one-half its expected life, and it provides a rate of return equal to or greater than most measures of the opportunity cost of capital in the private sector.

The data also reveal the following ranking of technical and economic parameters based on their impacts upon net benefits:

1) refuse-to-coal firing ratio
2) project estimates for the coal and ferrous metal price parameters 3/
3) rate of discount
4) initial capital investment

Summary and Implications

The results of the analysis indicate that the resource recovery prototype examined appears to be an economically feasible investment. This conclusion is substantiated by a majority of outcomes based on sensitivity analysis of five key technical and economic parameters examined under several benefit-cost and internal rate of return criteria.

The analysis also reveals the impact of the key technical and economic parameters on the economic feasibility of the prototype. These parameters, in order of importance, are: 1) the refuse-to-coal firing ratio, 2) projection estimates for coal prices, 3) rate of discount, 4) initial capital investment, and 5) net ferrous metal prices.

It should be emphasized that the primary thrust of resource recovery is to provide an economical, environmentally acceptable method of solid waste management. The recovery of energy and material resources is, in itself, a secondary goal. However, the fact that resources are recovered provides the main impacts for

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3/ Additional analysis revealed that when the coal and ferrous metal price parameters were considered separately, coal maintained a second place ranking and ferrous prices ranked fifth.

this research effort; such systems are attractive alternatives to traditional costly waste disposal practices because resource (energy and materials) recovery appears to be, at minimum, a break-even operation.

The Orrville case study provides quantitative support to the position that, given certain conditions, nonmetropolitan as well as metropolitan areas may find resource recovery to be an attractive alternative. Prerequisite conditions generally include: 1) the existence of an electric power plant capable of burning refuse, 2) the ability of the utility in question to burn enough refuse (100 to 200 tons/day [18]) to justify the expenditures required to convert the plant and construct and operate the solid waste processing facility, 3) a population base large enough to supply an adequate waste volume (e.g., 100 to 200 tons/day). Rising prices of conventional fuels and a lack of landfill space generally increase the desirability of resource recovery but are not prerequisites to its feasibility.

Secondary data indicates the existence of approximately 300 coal burning steam-electric generation plants in the nonmetropolitan counties of the United States. Present evidence on the specific characteristics of these plants and their surrounding waste generation areas is inadequate to make any conclusive statements on their technical and economic feasibility for resource recovery. However, it would appear that substantial potential exists. A regional resource recovery research project currently underway at Ohio State University is assessing this potential for the 12 North Central States [18].

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