AN ECONOMIC PERSPECTIVE ON

RESOURCE RECOVERY AND REUSE PROJECTS

KEY WORDS: Benefit-Cost analysis, Biogas, Economic analysis, Project evaluation, Resource recovery, Reuse.

ABSTRACT: There are technical and economic complementaries inherent in resource recovery projects which suggest that they may succeed where single purpose projects for solid waste recycling, composting, etc. have failed in the past. The controversy surrounding the economic potential of such projects in developing countries can only be assessed on a case-by-case basis within the framework of project evaluation. In applying such a framework, there are both theoretical and practical difficulties with a project definition based on sequentially separable components. The more general framework of multi-purpose project evaluation is thus recommended except for special cases where joint products are insignificant and technology choice is limited.

While some difficulties arise in the practical application of the MP model, these do not preclude the development of useful guidelines for project design, pricing and cost recovery policies. For those functions with unquantifiable benefits indirect methods can be used to check on project justification. Marginal cost pricing based on separable costs can be adapted to include long term incremental costs for lumpy investments. Joint cost allocation problems can be approached from a variety of directions depending upon the project's financial objectives, beneficiary preferences and linkages with other sectors. By proceeding with such carefully tailored applications of conventional project analysis, a body of reliable data on the economic potential of RRPs can be developed which may point the way to the most productive areas for further technical research and development efforts.

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DeAnne S. Julius[1/]

Introduction

Over the past decade public concerns in several different areas have focused attention on the potential for resource recycling and recovery. The pollution problems created by the disposal of large quantities of human and industrial wastes is a major concern in urban areas of both developing and industrial countries. At the same time, energy shortages and rising natural resources prices have intensified the search for alternative energy sources and encouraged an examination of the reuse potential of various waste products. Access to chemical fertilizers is difficult in isolated rural settings in the developing world, but crop yields can be dramatically improved with the application of organic fertilizers. The conversion of unwanted biological or industrial outputs into valuable agricultural or energy inputs could have important economic, as well as scientific, implications. There is, however, considerable scepticism about many of the claims being made for recycling. Commercially successful reuse applications are still the exception rather than the rule. Furthermore, the economic evaluations of such systems that have been carried out to date have produced mixed results and most have been methodologically flawed.

The purpose of this paper is to present and compare two alternative frameworks for the design and evaluation of resource recovery projects (RRPs); one which is typically (if implicitly) employed in the bulk of the technical literature on reuse, and the second a more general specification used by

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1/ Project Economist, Energy Department, World Bank. The views expressed are those of the author and do not represent those of the World Bank. The author is grateful to Messrs. R. G. Feachem, F. Golladay, J. M. Kalbermatten and D. Lauria for comments on an earlier draft.

economists to deal with "joint product" technologies. It is suggested that the second has several important advantages for clarifying design issues and avoiding common mistakes in project evaluation. The practical problems of applying the model to RRPs which involve unquantifiable benefits are discussed, and an example is presented to illustrate the recommended procedure.

Reuse as an Economic Process

The economic evaluation of resource recovery and reuse schemes is essentially a matter of project analysis. The relevant question is how to design a project which promotes the best mix of resource use, resource disposal, and resource recycling. The economist's definition of a project, however, is a broad one which focuses on inputs and outputs rather than the the process itself. Thus conservation policies, new production technologies which generate fewer (or cleaner) waste products, and existing disposal methods are all alternatives to recycling which must be comparatively evaluated.

The economic feasibility of RRPs should be determined by comparing the value society places on those resources used in the project with the value it attaches to the corresponding output. This exercise generally entails three steps. The first is to identify relevant inputs and outputs which are needed or produced by the project. The second step is to apply values to these inputs and outputs to ensure that they are expressed in a comparable metric. On the cost side, this often implies adjustments to reflect the timing of costs; the use of shadow, or efficiency, prices; border pricing of traded and non-traded goods; and the use of various conversion factors for labor, capital, foreign exchange, etc. On the

benefit side, in addition to timing adjustments, the social weighing of benefits according to income groups is sometimes advised.[1/] The third step of project evaluation involves the cost-benefit comparison. Various types of investment criteria can be used depending upon the project circumstances. The most frequently employed measures are the net present value, the internal economic rate of return, and the benefit-cost ratio. A further step which is sometimes included involves the testing of results for sensitivity to uncertainty or risk. The application of this basic project evaluation technique to RRPs is not a straightforward problem. The most difficult, but basic, question is the definition of the project and, therefore, its inputs and outputs. Because RRPs, by their nature, involve certain resources which are both outputs and inputs, it is sometimes unclear where project boundaries should be drawn or how individual project components should be evaluated.

The Sequentially Separable Project

The framework for project design which is most frequently found in the literature on RRPs involves a sequentially separable (SS) project definition. This reflects the technical design of RRPs which usually consists of a series of processes (e.g., waste treatment, fish farming, crop irrigation) where some of the outputs of the first are used as inputs for the next, and so forth. Each process is designed as a separate unit,

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1/ For more detail see L. Squire and H. van der Tak, Economic Analysis of Projects, John Hopkins University Press, 1975.

and often different individuals are involved in each design (e.g., sanitary engineers, marine biologists, agronomists).

Figure 1 is a schematic representation of an RRP with three processes (T_1, T_2, T_3), each with an input vector (I_1, I_2, I_3) and an output vector (O_1, O_2, O_3). For T_2 and T_3 the input vector is composed of joint inputs (I_{2J}, I_{3J}), which originate in previous processes, and separable inputs (I_{2S}, I_{3S}), which originate outside the RRP.[1/] Similarly, T_1 and T_2 produce both joint outputs (O_{1J}, O_{2J}), which are used as inputs into other processes, and separable outputs (O_{1S}, O_{2S}).[2/] Using this terminology, then,

$$O_{1J} = I_{2J} \quad \text{and}$$

$$O_{2J} = I_{3J}$$

where all Os and Is are quantity vectors.

If the design of such an RRP is handled by separate specialist teams it is usually necessary to specify O_{1J} and O_{2J} so that each team can properly scale its design. Suboptimization for each component is achieved by maximizing its net present value.[3/] For T_1, the relevant equation for determining both its output level and its capacity, or design

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1/ $I_{1J} = \emptyset$ so $I_1 = I_{1S}$

2/ $O_{3J} = \emptyset$ so $O_3 = O_{3S}$

3/ In theory, the present value of social net benefits should be maximized, but the determination and use of social weights is not considered in this paper since it cannot be applied routinely for projects whose benefits are not quantifiable. The notation and much of the analysis in this section proceeds from work by C. W. Howe, and additional information can be obtained from his referenced paper.

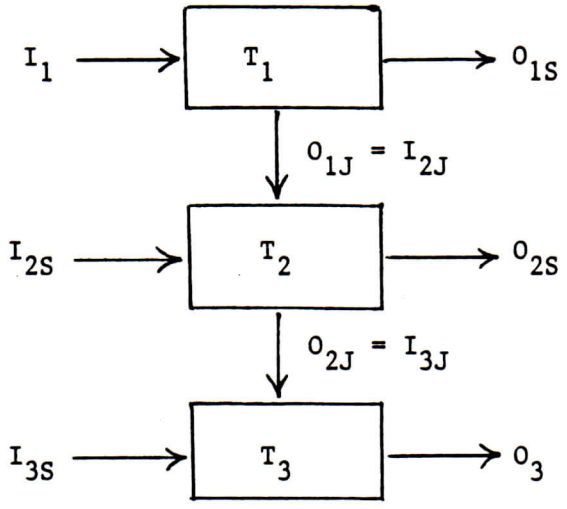

Figure 1. Sequentially Separable Project Definition

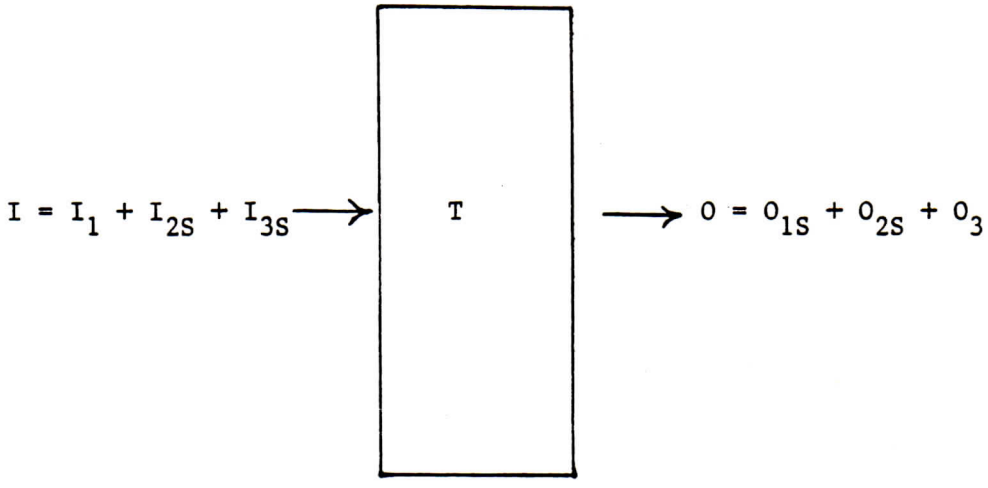

Figure 2. Multi-Purpose Project Definition

feature (X_1), would be

$$(1) \qquad \max_{O_1,\, X_1} \left\{ \phi_1(O_1, X_1) = -K(X_1) + \sum_{t=1}^{T} \delta_t \left[B_{1t}(O_{1t}) - C_{1t}(O_{1t}, X_1) \right] \right\}$$

where $K(X_1)$ = construction costs of process 1 capitalized to a common point in time

δ_t = $1/(1+r)^t$ where r is the social discount rate

$B_{1t}(O_{1t})$ = the total willingness-to-pay associated with O_1 in year t

$C_1(O_1, X_1)$ = the operating costs incurred in year t to produce outputs O_1 using process X_1.

There are two ways that joint inputs and outputs can be handled in this sub-optimization framework. One is to let their costs reflect alternative uses so that C(O, X) might have negative as well as positive components where the cost of joint inputs which would otherwise have to be disposed of would be negative. The second, and more typical, approach is to maximize over O and X subject to constraints on I_J and/or, possibly, O_J.[1/] Where the design options are few and discontinuous, the second method may yield the same results as the first. In general, however, this cannot be expected.

In RRPs whose "first" process involves the collection and treatment of some waste product, at least one component of I_1 is usually specified and often determines X_1. This in turn fixes $O_{1J} = I_{2J}$, which may

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1/ There may be no solution to the equation if both I_J and O_J are constrained.

set X_2, and so on. In practice, the design of RRPs often proceeds on this "sequentially separable" basis, possibly through a few iterations to allow feedback from T_3 to T_2, etc.

When the economic evaluation of an RRP also follows the SS framework, it is conceptually a fairly simple exercise of evaluating the net benefits of each component and aggregating. In practice, however, two major problems lurk. The first is the mundane but frequently encountered mistake of double counting the I_Js and O_Js. The evaluation of each component must include all associated Is and Os. In the aggregation across components, however, it is necessary to net out one set of joint costs. This becomes tricky when some costs are negative (as discussed above) or when various alternative project designs have different joint costs. A second, and much more serious, problem is that the SS framework may lead to the design and selection of sub-optional components. This is best illustrated by comparing the SS decision rule for component design (Equation 1) with that produced by an alternative framework.

The Multi-Purpose Project

Most RRPs can be considered as a special case of the broader category of multi-purpose projects (MP); i.e., projects which produce several outputs or whose output is used for several purposes. A typical example of a multi-purpose project is a dam which provides power, irrigation, flood control, recreational and/or other benefits. The distinguishing feature of a multi-purpose project is the technical complementarities (sometimes due to economies of scale) which exist among the purposes the project serves. A comparison of the "with and without" project scenarios

reveals the total project to be economically superior to any other combination of projects which produces the same outputs.

Viewed through the MP framework, the RRP represented in Figure 1 would look like Figure 2, where the input vector, I, is composed of I_1, I_{2S} and I_{3S} and the output vector, O, includes O_{1S}, O_{2S} and O_3. The details of the "block box" labeled T are not of particular interest to the project analyst except insofar as they represent the solution to the maximization problem:

$$(2) \quad \max_{O,\,X} \left\{ \phi'(O,X) = -K(X) + \sum_{t=1}^{T} \delta_t \left[B_t(O_t) - C_t(O_t,X) \right] \right.$$

where O and X are vectors of outputs and process design features, respectively. Equation (2) states that the objective of project design and evaluation is to maximize the present value of net benefits by choosing the appropriate sizes of plants (e.g., digestor capacity, pond size, etc.) and combination and levels of outputs. It places no constraints on subcomponent design.

The optimal design and output levels for the project components can be found by setting $\frac{\partial \phi'}{\partial x_i}$ and $\frac{\partial \phi'}{\partial o_{jt}}$ equal to zero, where x_i and o_j are individual items of the vectors X and O. Thus the appropriate design is that for which the marginal construction cost of each process x_i is just equal to the present value of the marginal operating cost savings for that process.

$$(3) \quad \frac{\partial K(X)}{\partial x_i} = - \sum_{t=1}^{T} \delta_t \frac{\partial C_t}{\partial x_i}$$

Further, the optimal output rate for each o_j is such that its price (p_{jt}) is equal

to the marginal operating cost in that year:

$$(4) \quad p_{jt}(o_{jt}) = \frac{\partial C_t}{\partial o_{jt}}$$

To the extent that consumer demands, and therefore project benefits, are functions of the output prices, deviations from marginal cost pricing will lead to sub-optimal project utilization and a net benefit reduction.

There are two further conditions which must be met for the project to be economically optimal. The sum of the present value of its net benefits must be greater than zero (or the economy would be better off without the project) and also greater than that of any alternative, mutually exclusive project. In particular, in selecting the proper combination of project components, the present value of each component must exceed the present value of all separable costs of that component on a "last added" basis. This is because each component must contribute a positive amount to the overall project's net present value in order to justify its inclusion. However, the costs and benefits which should be included in the component NPV calculation are only those which are separable (i.e., the costs of I_S and O_S) from the other project components. Thus, to the extent that there are joint costs (i.e., that there are I_Js and O_Js), the component NPV test in the MP framework is less restrictive than that of the SS framework. For example, a biogas unit may not be economically viable when evaluated as a separate component since the import of liquid natural gas may be a less costly method of providing the same benefits. However, it might become feasible if it is evaluated as one component of a waste disposal project where some of its costs are not separable on a "last added" basis. In addition, it might be the optimal waste treatment option (because of the energy benefits it produces) while not being the least-cost one.

Under certain conditions the SS and MP frameworks will yield the same answers. When joint inputs and outputs are nonexistant or when the range of technology selection is so narrow that joint optimization permits a sequential solution,[1/] the SS approach provides a convenient simplification. However, for RRPs where the technical complimentarities are large (i.e., there are many and/or large I_Js and O_Js), the use of the SS framework can lead to sub-optimal project design.

Practical Problems and Implications

The application of the MP framework to the design and evaluation of RRPs presents several problems. The major ones stem from the cross-sectoral linkages which surround such projects, the unquantifiable nature of some benefits, the treatment of very long-term benefits, and the cost recovery problems which may stem from economically appropriate pricing policies. These are discussed in turn below, followed by an example which illustrates how project design and pricing decisions can be derived through the MP framework.

Cross-Sectoral Linkages

Because reuse projects by their nature involve linkages among projects and across sectors, their full costs and benefits are not normally captured within the framework of single project evaluation. For example, where the output of a recycling plant, such as fertilizer, is designed for sale to the public, the demand for fertilizer as an input to the agricultural sector must be assessed. This demand, of course, is a derived demand from

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1/ In the language of linear programming, the relevant conditions are those for partitioning the matrix.

the sale of agricultural output. Thus without information on the agricultural sector, competing fertilizer products, and the transportation network, it is impossible to properly evaluate the value of compost produced for sale as fertilzer.

The methodologically appropriate solution to this problem is to develop an econometric model which is sufficiently disaggregated to test the "with and without" project scenerios. However, except in unusual circumstances, such an elaborate procedure is not appropriate for project evaluation. Instead, it is usually sufficient to gather information on other relevant sectors directly and rely on sector experts to estimate future price and consumption trends. This "partial equilibrium" approach will be an acceptable short-cut as long as the output(s) of the RRP make up a relatively small portion of the total production and consumption of the product(s). However, even in such cases it will be necessary for the project analyst to collect more information from diverse sources than is usual for project evaluation.

Unquantifiable Benefits

A second problem in evaluating reuse projects is that unquantifiable benefits such as reduced environmental pollution and improved community health are often the major outputs of some components. The difficulty of benefit measurement has long been a problem for public utility projects, and methods have been developed which allow the analyst to make informed investment choices in the absence of benefit measures. These involve a careful consideration of appropriate (including least-cost) technologies, honing the available alternatives to maximize benefit achievement from

each,[1/] and presenting the alternatives with their costs to the ultimate user for final selection. Pricing plays a key role since consumer willingness to pay triggers investment choices. Thus when benefits cannot be quantified the emphasis shifts to project design considerations as they relate to benefit achievement and output pricing.[2/]

Some of the benefits of RRPs can be quantified, of course. Marketable products such as methane and fish are easy to identify and evaluate. The value of compost can be set with reference to chemical fertilizer on the basis of its NPK contribution, adjusted for differential transportation and application costs. Where no market currently exists for an RRP output such as compost, or where consumer information on its potential benefits is poor, the benefit valuation may not have a direct relationship with the appropriate product price (see below).

Long Gestation Benefits

An additional problem with the economic evaluation of RRPs is that some benefits materialize only gradually over the long run. It may take many years to reverse a process of environmental decline. However, it is difficult to extend economic techniques, which involve the discounting

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1/ See, for example, J. M. Kalbermatten, D. S. Julius and C. G. Gunnerson, Appropriate Sanitation Alternatives: A Technical and Economic Appraisal, World Bank, 1978, Chapter 4 for a discussion of the approach to optimizing health benefits through sanitation system design.

2/ The literature on project evaluation in the absence of benefit measures is voluminous. One good reference for the non-economist is J. Hirshleifer, J. deHaven and J. W. Milliman, Water Supply: Economics, Technology and Policy, University of Chicago Press, 1960.

of future values, to cover cases where benefits are deemed to be important regardless of when they accrue. Societies which judge environmental preservation to be a high priority may wish to place no discount upon the future realisation of such benefits. However, this would imply that such a society would be indifferent between receiving those benefits 50 years hence and receiving them tomorrow. This extreme is also unrealistic, but the problem of the proper method of evaluating very long-term benefits has not been resolved.

Output Pricing and Cost Recovery

As shown above in Equation (4), the optimal pricing rule for multi-purpose projects is to set prices equal to marginal costs in each period. For "lumpy" projects with large, infrequent investments such a rule would imply sudden and drastic price increases in the years when capacity expansions were undertaken. For this reason, and to provide a more understandable pricing signal to the consumer, a long run marginal cost measure is often recommended as a better practical pricing guide.[1/]

Output pricing for multi-purpose projects presents a further difficulty in identifying which costs are incremental with respect to a particular output and which are shared (joint) costs pertaining to more than one output. The theory of separable costs is that each component should be costed on a "last added" basis. But as projects become more complex and as component design is optimized over the entire project as the

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1/ See R. Saunders, J. Warford and P. Mann, "Alternative Concepts of Marginal Cost for Public Utility Pricing: Problems of Application in the Water Supply Sector," World Bank Staff Working Paper No. 259, May 1977.

MP framework provides, separable costs become more difficult to identify. For example, suppose the optimal height of a dam for municipal water supply is 10 meters, while the optimal power generation project would require a 15 meter dam. The construction cost of the additional 5 meters is probably easy to estimate; but the incremental operating costs involved in running a larger facility and all of the smaller incremental design modifications can be very difficult to cost.

Where joint costs are large, and where prices are set according to separable marginal costs, the result is likely to be a sizeable financing gap. Some method is needed to allocate the joint costs to the various beneficiaries. The most commonly used methods include "separable cost-remaining benefits," "proportionate use of facilities," and "alternative justifiable expenditure." While each of these has some intuitive appeal under certain circumstances, there is no economic justification for preferring any one over another. The only economic principle to be followed in joint cost allocation is that fixed charges should be levied against beneficiary groups rather than increasing unit prices above marginal costs.

Economic Evaluation of RRPs: An Example

These principles of pricing and cost allocation can perhaps best be illustrated through an example. Figure 3 presents a schematic representation of a hypothetical RRP which provides for treating human and animal wastes through oxidation ponds, fish ponds, biogas digesters and drying beds to produce fish, fertilizer and methane. Table 1 lists the major items of capital expenditure and Table 2 shows annual operating cost. In the "product" column of each table is indicated the products, or outputs, to

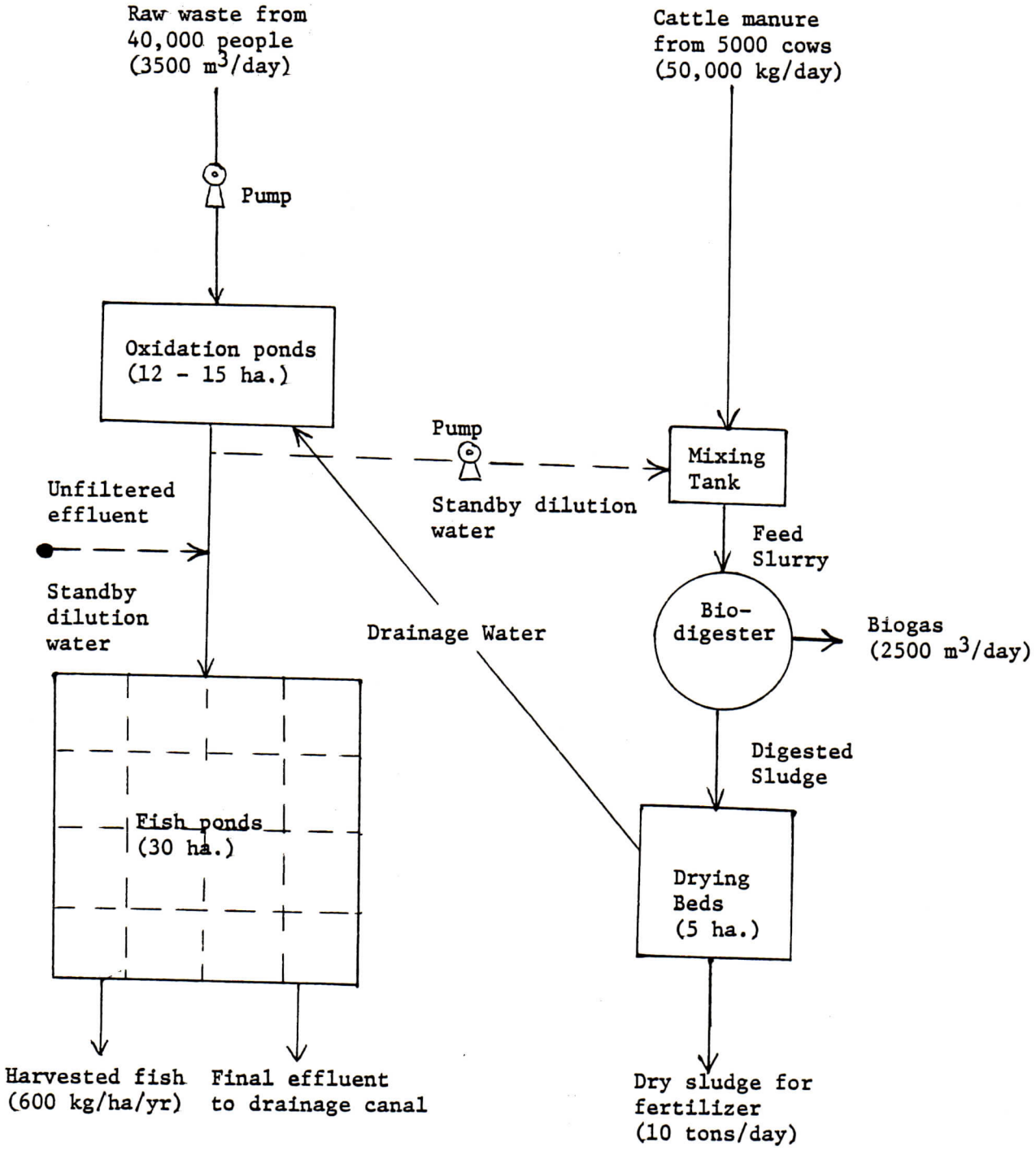

Figure 3. Hypothetical integrated wastewater treatment, effluent reuse and bio-energy recovery project.

Table 1. CAPITAL COST OF EXAMPLE RRP

Item	Cost	Product	Separable Product
Civil Structures			
Wastewater sump and pump station	5,000	W	W
Grit chambers	5,000	W	W
Oxidation ponds (different design without fish ponds)	100,000	W,A,G	-
Fish ponds	250,000	A	A
Cattle manure homogenisers	3,000	G,F	G
Biogas digestors	42,000	G,F	G
Gas compression, storage, piping	15,000	G	G
Sludge drying beds	10,000	F	F
Laboratory and office	10,000	W,A,G,F	-
	440,000		
Mechanical Equipment			
Wastewater pumps	15,000	W	W
Tractors and trolleys	30,000	G,F	-
Homogeniser mechanism	4,500	G,F	G
Digestor heat exchange system	25,000	G,F	G
Mixing and other equipment for digestor	18,000	G,F	G
Gas compression and storage equipment	15,000	G	G
Laboratory equipment	5,000	W,A,F,G	-
	112,500		
TOTAL	552,500		

which that item contributes, where A = aquaculture, F = fertilizer, G = biogas, and W = waste treatment. The relevant question to ask in completing the product column is "would this cost be incurred if only A (F, G, W) were being provided?" Thus it represents a cost breakdown on a "first layer" basis assuming that the functions were carried out by a single purpose project. The "separable product" column answers the question "would this cost be incurred if function A (F, G, W) were added to a project already designed to provide the other three functions?" Items which are jointly used for several functions often will not be separately allocable to any one since they would have been included with a "previous" function and thus are not incremental on a "last added" basis. An index of the degree of technical complementarity in a project is the proportion joint costs make up of the total.

In this example only a gross cost breakdown is presented. Without further details it is impossible to identify any separable products in the operating costs figures.[1/] In addition, no consideration is taken of the incremental design modifications which would be necessary for a thorough analysis of separable costs. For example, if aquaculture is considered on a last added basis, it is likely that some savings could be realized by a re-design of the oxidation ponds for waste treatment so that the net cost for the fishponds would be less than their total construction cost.

Once separable and joint costs have been identified, it is possible to prepare a functional breakdown of the total RRP cost, as shown in

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1/ In most RRPs there will be greater complementarities, and therefore fewer separable costs, in operating budgets than in capital costs.

Table 2. OPERATING COST OF EXAMPLE RRP

Item	Cost	Product	Separable Product
Salaries	400,000	W,A,G,F	-
Power	135,000	W,G,F	-
Spares, mechanical equipment maintenance	250,000	W,G	-
Miscellaneous	45,000	W,A,G,F	-
TOTAL	830,000		

Table 3. SEPARABLE AND JOINT COSTS OF EXAMPLE RRP

	Capital		Operating	
	$	%	$	%
Waste treatment	25,000	5		
Aquaculture	250,000	45		
Biogas	122,500	22		
Fertilizer	10,000	2		
Joint	145,000	26	830,000	100
TOTAL	552,500	100	830,000	100

Table 3 for this example. At this point a cross check of project design can be undertaken for the components with quantifiable benefits to see that the value of those benefits is at least as large as the component's separable cost and that no other project or configuration which could produce the same benefits could be built and maintained at less cost. If a component fails either of these tests then it should be dropped from the project.

Cost recovery objectives should next be pursued. First, the marginal cost per unit of each product should be determined. As discussed above, it is usually most practical to use an estimate of long run rather than short run marginal cost. For simplicity we assume that the design of the example RRP would be replicated at constant prices in the future so that a constant annuitization factor can be applied to the capital cost. If we further assume that all structures last for 20 years, that the facility is fully utilized from the beginning, and that the appropriate discount rate for the country where this project would be built is 10%, then capital costs can be converted into annual costs by multiplying by 0.117. The next step is to divide the annual (capital and operating) separable cost for each function by its expected annual output. Based on the output level given in Figure 3, the incremental costs of the example RRP would be $0.002 per cubic meter of treated wastewater, $1.63 per kilogram of fish, $0.016 per cubic meter of gas and $0.32 per ton of fertilizer. For those outputs whose value is fully represented by market prices,[1/] a further check on project design should be made by comparing

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1/ Waste treatment is a function for which this would not be true due to the large external costs imposed by untreated waste.

incremental costs with obtainable prices. It is important to include in this comparison any private costs which would be incurred in using the output; for example, the cost and time involved in hauling dried sludge from the drying site to farms.

Assuming that the project has been optimally designed and that the entire output will be demanded at prices set equal to incremental costs for all products, the final step in the project's economic evaluation is to allocate the joint cost among the beneficiaries. There may be good justification for some government financing in the case of projects involving such benefits as waste treatment. However, if alternative uses for public funds are deemed more valuable, it will be necessary to devise a system for recovering the joint costs of the project from its beneficiaries. As discussed above, there is no economic basis for choosing a particular cost allocation except that fixed rather than variable charges should be used. One possibility would be to split the joint costs according to the functions listed in the "product" column of Tables 1 and 2. Another is to distribute them according to price elasticities of demand for the various products, with the least elastic getting the largest cost share. Game theory solutions[1/] have also been suggested for joint cost allocation.

1/ Hamlin, S. S., W. A. Hamlin, Jr. and J. T. Tschirhart, "The Use of Game Theory in Evaluating Joint Cost Allocation Schemes," The Accounting Review, vol. LII, No. 3, July 1977, pp. 616-627.

Summary and Conclusion

There are technical and economic complementaries inherent in resource recovery projects which suggest that they may succeed where single purpose projects for solid waste recycling, composting, etc. have failed in the past. In addition, today's climate of rising materials and energy prices increases the value of the commercial benefits which RRPs can generate. However, the controversy surrounding the economic potential of such projects in developing countries can only be assessed on a case-by-case basis within the framework of project evaluation. In applying such a framework, there are both theoretical and practical difficulties with a project definition based on sequentially separable components. The more general framework of multi-purpose project evaluation is thus recommended except for special cases where joint products are insignificant and technology choice is limited.

While some difficulties arise in the practical application of the MP model, these do not preclude the development of useful guidelines for project design, pricing and cost recovery policies. For those functions with unquantifiable benefits indirect methods can be used to check on project justification. Marginal cost pricing based on separable costs can be adapted to include long term incremental costs for lumpy investments. Joint cost allocation problems can be approached from a variety of directions depending upon the project's financial objectives, beneficiary preferences and linkages with other sectors. By proceeding with such carefully tailored applications of conventional project analysis, a body of reliable data on the economic potential of RRPs can be developed which may point the way to the most productive areas for further technical research and development efforts.

APPENDIX I.—REFERENCES

1. Hamlin, S. S., W. A. Hamlin and Tschirhart, J. T., "The Use of Game Theory in Evaluating Joint Cost Allocation Schemes," The Accounting Review, vol. LII, No. 3, July 1977.

2. Hirshleifer, J., deHaven, J. and Milliman, J. W., "Water Supply: Economies, Technology and Policy," University of Chicago Press, 1960.

3. Howe, C.W., "On the Theory of Multiple-Purpose Water Projects: Identification, Design, Evaluation, Output Pricing and Cost Sharing." Draft Working Paper, Energy Department, World Bank, 1979.

4. Kalbermatten, J. M., Julius, D. S. and Gunnerson, C. G., Appropriate Sanitation Alternatives: A Technical and Economic Appraisal, EWT Department, World Bank, 1978.

5. Saunders, R., Warford, J. J. and Mann, P., "Alternative Concepts of Marginal Cost for Public Utility Pricing: Problems of Application in the Water Supply Sector." World Bank Staff Working Paper No. 259, May 1977.

6. Squire, L. and van der Tak, H., Economic Analysis of Projects, Johns Hopkins University Press, 1975.