COMPREHENSIVE RESOURCE AND ENERGY RECOVERY PROGRAM, BERKELEY, CALIFORNIA

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ABSTRACT

This paper is intended to present, as a case study, how the City of Berkeley is dealing with the institutional and decision making problems associated with the impending closing, due to diminishing capacity, of its inner-city municipal refuse landfill.

Cognizant of the negative impacts of solid waste disposal and the energy shortages felt by all municipalities in today's society, the City's approach is to combine solid waste disposal, and energy and materials recovery through the implementation of a Solid Waste Management Center incorporating recycling, source separation, transfer and energy production.

INTRODUCTION

The City of Berkeley, with a population of 125,000, is one of the few municipalities in the San Francisco Bay Area where refuse is collected by municipal crews and disposed of on land owned by the City. The disposal site is located at the Berkeley Marina and is operated by a private franchisee. It is estimated that the presently diked area will reach capacity by 1983-1985.

Earth Day, 1969, gave birth to the City's first recycling center. Since that time, a number of other recycling and waste reduction programs have been implemented in Berkeley:

1. A second recycling center.
2. A monthly residential, curbside, newspaper pickup program.
3. A monthly subscription pickup program for glass, cans, and newspapers.
4. A wine bottle washing project.
5. A plant debris composting project.
6. An ordinance requiring a deposit on beverage containers enacted by the City Council and pending in the Courts.

Anticipating the necessity for an alternative and more environmentally sound solid waste management system, the City Council established a Solid Waste Management Commission in 1972. The Commission was mandated to develop a short-term plan for reducing the quantity of solid waste generated and a long-term ecologically sound plan for managing the City's refuse in the future.

In 1973, in response to a recommendation by the Solid Waste Management Commission, the City Council decided to purchase a site for a solid waste transfer station. Shortly thereafter, two parcels of land were purchased not very far from the existing landfill.

In 1975, the City commissioned a report to assemble data on refuse generation and disposal in Berkeley and study the relationship of Berkeley's resource recovery alternatives to suggested regional plans. This report recommended that the transfer station incorporate recovery processes to ensure maximum reutilization of resources.

In 1976, the City Solid Waste Management Commission prepared a source separation and waste reduction plan. The Commission recommended to the City Council that curbside collection of source grouped materials be implemented.
and that the space be allocated at the proposed transfer station site to incorporate a storage depot for collected materials and a public recycling center.

Concurrent with the development of the Commission's plan, the future utilization of a proposed seven acre (28,329 m²) tract or the Marina landfill site became questionable due to action taken by the Corps of Engineers and the Regional Water Quality Control Board. Faced with the possibility of early closure of the landfill, the City Council approved a recommendation by the Public Works Department to contract with consultants for preliminary engineering of a Solid Waste Management Center at the recently purchased site. In June, 1979, Garretson-Elmendorf-Zinov-Reibin (G·E·Z·R) published *Solid Waste Management Center – Phase One*. A second report, *Solid Waste Management Center – Phase Two*, was funded by the State Solid Waste Management Board and published in September of 1978. The second phase study was sparked by the interest of local industry in utilizing energy produced from refuse at the Solid Waste Management Center (SWMC). Phase II identified and recommended appropriate scale resource recovery systems. Phase III, funded by E.P.A. and the City, and begun in August, 1979, has been undertaken by G·E·Z·R and its subsidiary, Brown, Vence and Associates. The purpose of this phase is to complete the SWMC planning including market negotiations, permits, financing, risk analysis, and procurement.

**PHASE I: A DISCUSSION OF RESULTS AND CONCLUSIONS**

The purpose of the Phase I study was to provide a master plan to:

1. Manage the City's solid waste in a reliable, economically feasible and environmentally acceptable manner.
2. Provide maximum flexibility for staged implementation of resource recovery options.
4. Manage wastes by early 1983-1985 when the existing landfill is expected to close.

As a means to achieve these goals, a phased Solid Waste Management Center was conceived which would incorporate:

1. A Storage Depot for source separated materials.
2. Recycling Center for reusable materials brought to the SWMC.
3. Transfer Station/Processing Station.

Approximately 64,400 tons (58,600 t) annually of municipal solid waste (MSW) will require handling at the Solid Waste Management Center. The refuse composition was estimated as shown in Table 1. All of the waste generation and composition data was compiled from previous studies conducted for the City.

A local marketing study was performed on materials recovered through source separation and mechanical processing. Additionally, a compost marketing survey was performed to determine if a suitable market exists for the compostable portion of the waste stream. Table 2 presents a list of materials that were felt to be potentially recoverable.

**SOURCE SEPARATION**

In an effort to reduce waste generation in Berkeley, a curbside source separation program was investigated. Cost estimates and types of source-grouped materials to be collected were examined.

Materials that were considered for curbside collection included:

1. Newspaper.
2. Cardboard.
3. Food and beverage cans.

The collection program was designed to transport these source-grouped materials from Berkeley's households and commercial establishments to the Storage Depot at the SWMC.

**RECYCLING CENTER**

The Recycling Center, as conceived, has the following provisions:

1. Receiving area for recycled materials brought to the SWMC by the public.
2. Covered “flea market” to allow direct sale of reusable items.
3. Information center to further efforts in waste reduction.

**TRANSFER STATION/MECHANICAL PROCESSING**

A Transfer Station utilizing low technology material separation was investigated to reduce waste quantities requiring long haul and increase quantities of resources reclaimed. In addition, if market commitments were secured for the "organic frac-
TABLE 1. COMPOSITION OF REFUSE TO BE HANDLED/PROCESSED AT THE SOLID WASTE MANAGEMENT CENTER

<table>
<thead>
<tr>
<th>Material</th>
<th>Residential Percent by Weight as Received</th>
<th>Commercial Percent by Weight as Received</th>
<th>Total Weighted Averages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Newspaper</td>
<td>10</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>• Cardboard</td>
<td>7</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>• Mixed Paper</td>
<td>11</td>
<td>21</td>
<td>14</td>
</tr>
<tr>
<td>Subtotal</td>
<td>28</td>
<td>33</td>
<td>29</td>
</tr>
<tr>
<td>Metals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Cans *a</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>• Other</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Subtotal</td>
<td>7</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Plant Debris</td>
<td>13</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Glass</td>
<td>9</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Miscellaneous *b</td>
<td>43</td>
<td>53</td>
<td>46</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

*a Ten percent of can fraction is assumed to be aluminum.
*b Includes food wastes, textiles, wood, plastic, rubber, waste oil, rock, and ash.

The results of the Phase I study indicated to the City that:
1. Implementation of the SWMC offers the City significant opportunity to recover currently wasted resources and reduce disposal costs that would be incurred by direct hauling to a distant landfill after closure of the existing site.
2. The least costly alternative considered involves some form of energy recovery in conjunction with a city-wide recycling center. There did not appear to be a strong market for "organic fraction" as RDF.
3. Local markets offering long term contracts with established floor prices exist for materials recoverable through source separation.
4. A transfer station should be constructed.
TABLE 2. POTENTIALLY RECOVERABLE MATERIALS AT THE SOLID WASTE MANAGEMENT CENTER

<table>
<thead>
<tr>
<th>Material</th>
<th>Recycling Center</th>
<th>Storage Depot(^a)</th>
<th>Transfer Processing Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Newspaper</td>
<td>X</td>
<td>X</td>
<td>X(^b)</td>
</tr>
<tr>
<td>• Cardboard</td>
<td>X</td>
<td>X</td>
<td>X(^b)</td>
</tr>
<tr>
<td>• Mixed Waste Paper</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Cans</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>• Other</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Waste Oil</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Wood</td>
<td></td>
<td></td>
<td>X(^b)</td>
</tr>
<tr>
<td>Grease</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Reusable Goods (White Goods,</td>
<td></td>
<td></td>
<td>X(^b)</td>
</tr>
<tr>
<td>Clothing, Books, etc.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Organics (^c)</td>
<td></td>
<td></td>
<td>X(^b)</td>
</tr>
</tbody>
</table>

\(^a\) For source grouped materials collected curbside.

\(^b\) Recovered as a refuse-derived fuel.

\(^c\) Plant debris not delivered to the City composting project can be recovered through the Transfer/Processing Station function as part of a RDF product.

which allows some materials recovery in a flexible manner to allow for staged development to further levels of resource and energy recovery if markets cannot be initially secured.

5. The nonrecycled “organic fraction” of the waste stream remaining after source separation is more appropriately burned for its energy value than composted due to lack of markets and the poor quality of the product.

6. If recovery of significant quantity of glass and aluminum is to be part of the City’s resource recovery program, a curbside collection program is recommended.

7. Direct haul of the City’s refuse to an available landfill after the closure of the existing site is the most expensive and recovers the least resources of any of the alternatives considered.

8. Eleven potential steam customers have been identified adjacent to the proposed SWMC site.

9. A second phase study should be implemented...
to provide the City with the necessary information for selecting the optimum solid waste management/resource recovery system.

**PHASE II: A DISCUSSION OF RESULTS AND CONCLUSIONS**

The work conducted in the Phase I study indicated that the City should investigate energy recovery further since markets were available adjacent to the proposed SWMC site. In addition, the local utility, Pacific Gas and Electric Company, expressed serious interest in utilizing the steam in a co-generation (electricity and low pressure steam) project. With this background, the Phase II study was implemented in order to:

1. Evaluate specific disposal alternatives.
2. Identify systems to recover resources and energy from the waste stream.
3. Examine the technical reliability, environmental acceptability, energy productivity, and economic attractiveness of resource recovery units.
4. Evaluate the compatibility of resource recovery systems with a city-wide source separation program.
5. Propose for further consideration a system which would provide the City with a technically reliable, environmentally responsible and economically attractive method for recovering resources and energy from solid wastes.

**DISPOSAL ALTERNATIVES**

In evaluating the economic feasibility of various resource recovery alternatives, the City wanted to identify and quantify the disposal (versus recovery) alternatives available. Specific distant landfill sites were evaluated using both direct haul and transfer concepts. In evaluating the alternatives environmental, energy and economic impacts were used to develop recommendations.

**RESOURCE RECOVERY ALTERNATIVES**

Appropriate resource recovery systems which produce marketable products and offer the flexibility of modular development were identified on the basis of preliminary marketing discussion with local industry, trade, literature, vendor contact, and comments from the City of Berkeley and the State Solid Waste Management Board. Systems not considered appropriate for Berkeley were eliminated from further consideration because of high cost, inadequate technological development, inappropriate scale, and/or inadequate market potential.

Candidate systems included the following:
1. Pyrolysis systems.
2. Waterwall combustion systems.
3. Package incinerators with heat recovery.
4. Refuse derived fuel (RDF) production system.

These systems were evaluated with respect to:
1. Marketability of end-products.
2. Degree of system demonstration.
3. Technical reliability.
4. Equipment durability.
5. Environmental ramifications.
7. Cost effectiveness.

In addition, during the course of the investigation fifteen refuse recovery facilities around the country were visited by the consultant and City staff. The purpose of the visits was to see first-hand what the facilities looked like and, more importantly, to talk to personnel involved with planning and operation.

Resource recovery alternatives and existing disposal alternatives were identified and evaluated on the basis of the least cost per incoming ton. This indicator was utilized as it most nearly parallels the increased disposal costs to be borne by the Berkeley citizens. The list that follows presents the finding with the least cost system first, all costs are mid-1978 dollars and do not include collection.

<table>
<thead>
<tr>
<th>Type of System</th>
<th>Net cost per ton</th>
<th>Cost/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Modular Incinerators</td>
<td>$ 9</td>
<td>$10</td>
</tr>
<tr>
<td>2. Transfer/Haul</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td>3. RDF Production</td>
<td>21</td>
<td>23</td>
</tr>
<tr>
<td>4. Direct Haul</td>
<td>29</td>
<td>32</td>
</tr>
<tr>
<td>5. BSP Pyrolyser</td>
<td>30</td>
<td>33</td>
</tr>
<tr>
<td>6. Andco-Torrax Pyrolyser</td>
<td>35</td>
<td>39</td>
</tr>
<tr>
<td>7. Waterwall Combustion</td>
<td>41</td>
<td>45</td>
</tr>
</tbody>
</table>

It should be noted that this ranking represents a site specific evaluation. It is not intended to be a comparison of alternate technologies, but simply how one community, Berkeley, California, should proceed in solving their waste management problems.

The results of the Phase II study indicated to the City that:
1. Implementation of the SWMC offers the City significant opportunity to recover currently
wasted resources, and reduction of disposal costs that would be incurred by direct hauling to a distant landfill after closure of the existing site.

2. The least costly resource recovery alternative considered for the Solid Waste Management Center is a Modular Incinerator System producing steam. A Modular Incinerator System utilizes the energy value of solid waste to heat water to produce steam. Solid waste is fed into a primary chamber, where it is burned slowly under controlled air conditions. The resulting hot gases are passed through a second chamber, where excess air is injected to allow complete combustion. Auxiliary fuel may be required in minimal quantities to maintain proper combustion temperatures. The particulate matter burns off, and the hot effluent is passed through a waste heat boiler to produce steam. The steam can then be used to generate electricity with the addition of a turbine generator, if desired. The incinerators are factory built, highway shippable, and can be assembled into clusters of two or three.

3. A Modular Incinerator System can recover up to 66 percent of the refuse to be handled at the SWMC. Remaining residues will require landfilling.

4. Based on recent improvements in equipment, the redundancy of modular components, and the operating experience of existing facilities, Modular Incineration can be considered a reliable technology.

5. Two currently unanswered environmental questions remain which are common to all the resource recovery systems evaluated—the extent of air pollution, and the classification of residuals (bottom and fly ash). The analysis being conducted by the Environmental Protection Agency and the State Solid Waste Management Board on the Modular Incinerator facility in North Little Rock, Arkansas, is expected to supply required data to resolve these issues. There are no other unmitigable environmental impacts with respect to a Modular Incinerator System.

6. Eleven (11) entities (private firms and public institutions) have expressed interest in purchasing refuse derived steam produced from the proposed Berkeley facility.

CONCLUSION

As a result of the efforts of Phase I and Phase II the City has taken a course of action which includes:

1. Construction of a Solid Waste Management Center with resource recovery and transfer capabilities. This will minimize additional disposal costs after closure of the existing landfill site.

2. Pursuing development of a Modular Incinerator System producing steam. Some pre-processing of the refuse should be investigated to improve combustion, reduce ash production, increase reliability, and increase quantity of secondary materials reclaimed.

3. Operation of the energy recovery facility should be by a private firm experienced in the operation of package incinerators. Experience of similar facilities throughout the country indicate that municipalities generally lack the capability to operate sophisticated mechanical facilities and do not have a management structure which is flexible enough to handle this type of operation.

Before construction of the Solid Waste Management Center further efforts to complete the overall planning will include:

1. Confirmation and negotiation of markets for recovered materials and energy.

2. Waste stream analysis including weighing, sampling, and laboratory analysis over a period of one year. Outputs from this effort will also be used to determine how the curbside collection program affects the Resource Recovery Facility’s waste stream.

3. Examination of possible front-end processing technologies as they pertain to modular incineration.

4. Assessment of all applicable environmental constraints, and required approvals and necessary permits.

5. An accurate cost estimate of the proposed project as presently defined.

6. Identification of the numerous elements of risk associated with this project.

7. A financing plan which is best suited to this project and the Berkeley situation.

8. Development of the most compatible procurement approach.

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Chiu, Peter, and Diaz, Luis, *Development of a Solid Waste Transfer Station in the City of Berkeley*, June 6, 1975.

Key Words
Boiler
Combustion
Design
Environment
Management
Market
Refuse