ENERGY FROM WASTE: AN EVALUATION OF CONVERSION TECHNOLOGIES

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Executive Summary

This report presents the findings of an evaluation of the technical and economic status of 'novel' process technologies for recovering energy from municipal solid waste, and assesses the environmental impact of their operation. These technologies include:

—biological processes (landfill gas recovery, in-plant anaerobic digestion and hydrolysis/fermentation);
—refuse-derived fuel (RDF) manufacture and combustion, including use of fluidised bed systems;
—pyrolysis/gasification.

ERL concludes from the considerable full-scale operating experience of methane recovery from landfill now existing, that while scope exists for optimisation of methane yield/purification of the gas through micro-biological research and improved site-management techniques, the process has considerable commercial potential for further development on larger and suitably situated landfill sites. Gas extraction generally improves the stability of the landfill site and reduces the hazard potential associated with gas migration.

Other in-plant biological processes remain at an early stage of development. Because of their high cost, low energy efficiency, need for water addition and several outstanding operating problems, it is unlikely that these technologies will make an economic contribution to energy recovery from municipal waste in the medium-term future at least. The most likely possible application would be biological treatment in combination with sewage sludge or agricultural wastes. Because of the nature of the sludge and effluent produced from these processes, they offer few environmental benefits and could possibly have adverse impacts compared to landfill disposal of municipal waste.

A number of RDF plants are now operating in the Community, and from the limited though generally satisfactory combustion experience gained so

far, particularly with pelletised fuel, it would seem that the technology has real technical and economic potential, in most cases for co-firing in industrial coal boilers. Application of fluidised bed technology would appear particularly appropriate for RDF firing. Combustion of RDF generally results in somewhat lower emission levels of pollutants than from coal or raw refuse incineration, but organic micro-pollutants are the subject of continuing investigation.

Following poor operational and economic performance of plants built in Europe and the USA in the 1970s, there is renewed interest in pyrolysis as an energy recovery process for refuse, especially in Germany where there are two pilot/demonstration projects (one full-scale plant also operates in France). Pyrolysis has the highest energy conversion efficiency of all 'novel' technologies, but the system's long-term reliability remains to be established. Overall, the processes present no significant adverse environmental impacts, although a better understanding is needed of the level of acid gases and possibly of trace heavy metals remaining after combustion, together with the optimum means of control. Alkaline scrubbing is high cost and involves large quantities of water requiring further treatment.

All energy from waste process plants require proper internal controls on dust to avoid occupational health risks, attention to amenity considerations and, in the case of pyrolysis, avoidance of gas leaks which might present a toxic and/or explosion hazard to plant workers. Local factors, particularly fuel markets, have a major influence on the future economic viability of the processes.

The report also considers the merits of standardising specification parameters for RDF and means of future dissemination of operating experience and of addressing specific technical and economic problems encountered with these processes.

Acknowledgements

The authors gratefully acknowledge the following for permission to reproduce: Fig. 5.2(a), from 'Gas production during refuse decomposition', by G. J. Farquhar and F. A. Rovers, *Water, Air and Soil Pollution*, 1973, **2**; Reidel Publishing Co., The Netherlands; Fig. 5.2(c), K. & U. Hofstetter AG, Switzerland; Fig. 5.3(b), Waste Management, Inc., Florida, USA; Fig. 5.4(a), Dornier-System GmbH, West Germany; Fig. 6.2(a), AB Eksjö Energiverk, Sweden; Fig. 7.1(b), Kiener Pyrolyse Gesellschaft für Thermische Abfallverwertung mbH, West Germany; Fig. A1, Fläkt AB, Norway; Fig. A3.3(a), PLM Miljöteknik AB, Sweden; Fig. A4.1, Andco-Torrax Caliqua, France; Figs. A4.2(a–d), from *Materials and Energy from Refuse*, ed. A. Buekens, Koninklijke Vlaamse Ingenieursvereniging, Belgium; Table 3.2(a), Motherwell Bridge Tacol Ltd, England; Tables A3.3(a–b), Svenska Renhållningsverks, Sweden; Tables A3.3(f–j), National Center for Resource Recovery, Inc., Washington, DC, USA.

CONTENTS

1. INTRODUCTION

1.1 Study Objectives

This study, carried out under contract no. U/82/186, aimed to assess the status of development of novel methods for recovering and utilising energy from municipal solid wastes (other than incineration), notably in respect of their potential impact on the environment, and the results and experiences acquired to date.

In particular, the study focuses on:

- Biological treatment methods to extract energy,
- Production of fuels,
- Combustion of fuels, including fluidised bed systems.

1.2 Approach

1.2.1 Work Method

In carrying out its appraisal of the energy from waste technologies, ERL

- reviewed available published data and reports concerning technologies under development, being tested or in use, both within and outside the Community;
- held discussions with other relevant experts;
- conducted site visits and held in-depth discussions with plant operators and personnel concerned with operational and pilot plants.

Based on such data and information gathered, ERL developed the findings and conclusions presented in this report.

It is the nature of an investigation of developing technology that the situation is dynamic. The findings of this report necessarily relate to the situation at the time of writing. Certain technologies, in particular hydrolysis, are at an early stage of development. Others, for example RDF production, are well advanced. These differences are reflected in the coverage possible in this report and for these 'infant' technologies inevitably some of the conclusions drawn are tentative.

1.2.2 Presentation of Results

The availability of information has implications, both in terms of the level of detail in which the different processes can be reviewed and the scope for any comparative evaluation. In particular, reliable cost information relating to certain commercial developments is difficult to obtain. In any case, for schemes at an early stage of development, costs of full scale plants are difficult to assess from experience gained on small scale pilot work.

Technical and environmental aspects of process technologies are generally not dependent on the specific design and location of plant. However, general conclusions on the economic feasibility of a particular process technology are generally difficult to draw, and are dependent on the particular location. The latter would affect alternative disposal routes available, their costs and the local markets for fuel and other process products, etc. However, the report comments upon the economic characteristics of the types of processes considered for energy recovery from waste.

1.3 Report Layout

The report has seven main sections:

- o Section 2 places energy recovery from wastes in the context of municipal waste management and national and Commission objectives in energy use, environmental protection, waste management and resource recovery.
- o Section 3 outlines our findings and conclusions and recommendations.
- o Section 4 describes in general terms the broad types of technology available, their basic features and the interaction of energy recovery and materials.
- o Section 5 evaluates biological processes, including landfill gas extraction, engineered anaerobic digestion systems and hydrolysis/fermentation.
- o Section 6 evaluates the production and firing of refuse derived fuels.
- o Section 7 evaluates pyrolysis/gasification systems.

1.4 Acknowledgements

In the course of ERL's investigations, we obtained information and comments from a large number of private and public organisations in Europe and North America. A list is included in Appendix 1 and we would like to take this opportunity to thank them all for their cooperation and assistance. The response to our requests for information was most encouraging for the future utilisation of energy from waste technologies in the EEC.

The team would also like to thank Directorate Generals XII and XVII of the Commission and their contractors for allowing us to be involved in their coordination meeting.

2. THE CONTEXT OF ENERGY RECOVERY FROM MUNICIPAL SOLID WASTES

2.1 The Role of Waste Disposal Authorities

The prime responsibility of waste disposal authorities is to dispose of municipal wastes in a manner which preserves the environment and protects public health at least possible cost.

Sanitary landfill is still the most widely practised disposal method adopted in Member States and elsewhere and, provided suitable sites located conveniently to the centres of waste generation can be secured, is likely to remain so.

As far as the waste disposal authority and its responsibilities are concerned therefore, any further handling or processing of the wastes, including processing for energy recovery, must show financial benefits in terms of income from sale of resources (materials and/or energy) and savings relative to the costs of traditional alternative methods of waste disposal. Figure 2.1(a) overleaf presents the decision framework in which municipal authorities will evaluate energy recovery from municipal waste technologies, and the key influencing factors.

2.2 The Perspective of National Governments

National governments may well take a rather different view of resource recovery from wastes. This may result from taking a longer term view of the use of natural resources and the implementation of energy conservation/rational use of energy policies, the potential import savings on fuel or raw materials and other factors. This concern may manifest itself in encouraging/persuading industry and local authorities to recover more resources from waste through introduction of cash incentives, fiscal measures or other controls to influence the market. The degree of intervention in the market varies with Member States' policies in these respects.

2.3 The Objectives of the Commission of the European Communities (CEC)

The CEC has a number of declared objectives of direct relevance to the consideration of energy recovery from municipal solid wastes which must be borne in mind in any evaluation. Encompassed in Directives and Recommendations these include:

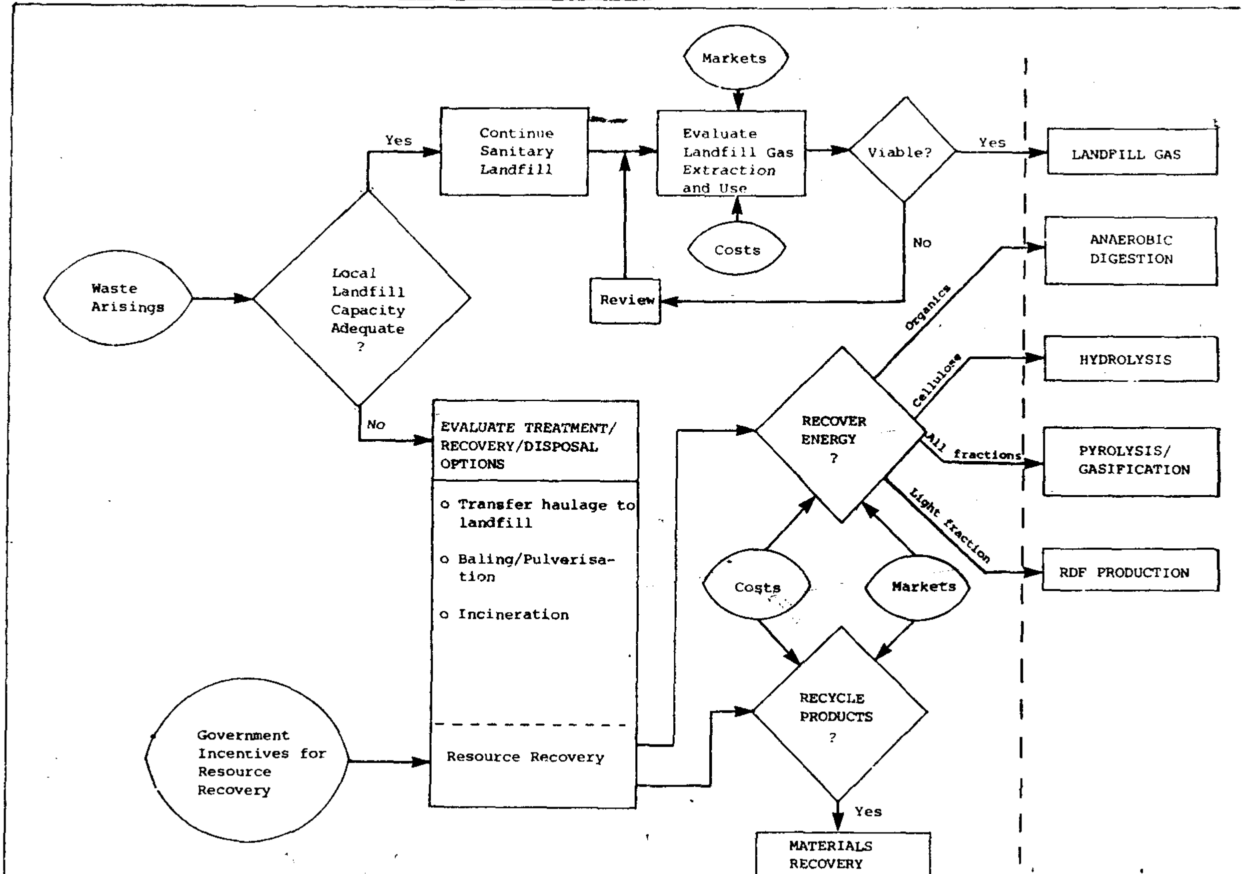
i. The framework Waste Directive (75/442/EEC), OJ No. L194 25 July 1975) covering:

   a) the prevention and reduction of waste

   b) the recycling and reuse of waste

   c) the safe disposal of waste which is not recovered.

FIGURE 2.1(a): ENERGY RECOVERY DECISION FRAMEWORK



ii. Council Directive on air quality limit values and guide values for SO_2 and particulates (80/779/EEC), OJ No. L229/30, 30 August 1980.

iii. The recommendation concerning the reuse of Waste Paper and the use of recycled paper (81/972/EEC), OJ No. L355/56, 10 December 1981, covering inter alia, the encouragement of the use of recycled paper and board.

2.4 Potential Fuel/Energy Users

Potential users of the fuel or energy produced from refuse fall broadly into four groups:

i. industrial or commercial energy consumers with boilers and kilns based on solid fuel (usually coal) whose fuel systems might be suitable for various alternative cheaper fuels based on solid wastes;

ii. industrial or commercial users who can adapt boilers or power plants to run on gas produced by landfills, anaerobic digestion processes or pyrolysis/gasification plants;

iii. industrial, commercial or domestic users of hot water/steam for process/space heating who might be interested in being supplied via a district heating network;

iv. utility companies who would purchase purified gas or surplus electricity for trunk/grid distribution.

Refuse Derived Fuel (RDF) has a higher ash and moisture content than coal and a lower calorific value. Existing boilers designed for coal firing may therefore need modification and additional operating cost, including labour, may be required. The price of RDF must be sufficiently lower to more than offset any such cost disadvantages. Reliability of supply will also be an important factor, together with adequate controls on product quality. Untreated landfill and biogas has only half the calorific value of natural gas and so users must similarly be offered the fuels at discounted prices, quality control may also be a consideration.

Solid fuel boiler operators, raising steam and hot water for a variety of process and space heating purposes have the following overall objectives:

i. to minimise total energy utilisation costs, including fuel preparation, handling, ash disposal and boiler maintenance costs, as well as fuel firing;

ii. incorporated within (i), not to add significantly to manpower costs, either in terms of numbers of operators or level of skills required;

iii. trouble-free operation;

iv. reliability of fuel supply;

v. to meet any legal requirements of local air emission control.

Users of energy recovered from municipal wastes will need to be located close to the waste/energy recovery plant facility to make supply feasible and economic, particularly in the case of landfill and anaerobic digestion process gases.

Thus it may be seen that while fuel derived from municipal solid waste clearly offers a potentially valuable fuel supply to industry, it must be marketed by the producers in such a way and at such a price that it provides an attractive economic and operational alternative energy source for the user.

In some instances, producer and user will be the same organisation and this has associated benefits in both cost and organisational terms. It may also prove advantageous in removing the energy consumption of fuel delivery to consumers from the energy balance equation.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 Criteria of Evaluation

The conclusions of the study present the principal findings of our investigation into the current status of the energy recovery technologies described in the Introduction. They are considered in terms of their technical status of development and the environmental aspects associated with their operation, commenting upon their overall potential economic viability.

After assessing the individual process technologies a few general conclusions are drawn and recommendations given regarding their future development and use.

BIOLOGICAL PROCESSES

3.2 Landfill Gas Recovery

3.2.1 Technical/Development Status

Extraction of gas (principally methane, but also CO_2 and certain other hydrocarbons and impurities) from municipal waste landfill is being practiced or is under full-scale development in nearly 50 sites within the Community. In the USA, there are some 22 sites currently operating, several others under development.

The principal technical issues relate to purification of the gas produced so as to improve its calorific value and potential for utilisation and to optimise the overall methane yield from the crude anaerobic digestion processes on site. Most basic research is directed to micro-biological investigation into the systems of acetogenesis and methanogenesis, and development of more selective micro-organisms which, under different conditions, will increase the yield of methane in relation to other gases. Site management development work is concerned with improving the conditions for methane generation through wetting, compaction and/or nutrient supply.

3.2.2 Economic Aspects

The economics of methane recovery from landfill is critically determined by the availability and type of local outlets for the gas. To the extent that consumers (e.g. brick kilns) are able directly to utilise relatively impure gas, long pipelines can be avoided, so the economic viability of the process improves. On-site electricity generation with gas engines (possibly with heat recovery) can be the most economic energy recovery option if there are no local gas outlets. Many fully commercial systems are in operation, although investment in methane recovery on several sites has been substantially influenced by the need to extract methane for safety reasons, where gas migration is a problem.

There is little doubt that considerable economic potential exists for methane recovery from landfill sites as further improvements in methane yield/purity are obtained through optimisation of site management techniques and, possibly in the longer term, through micro-biological developments in controlling the anaerobic digestion process. It is probable that the minimum size of landfill sites for economic exploitation/gas recovery is around 1 million m^3.

3.2.3 Environmental Impacts

The potential emissions, and the associated potential impacts and hazards of methane recovery/landfill systems are summarised in Figure 3.2(a) overleaf.

Gas extraction from municipal waste landfill is generally environmentally beneficial, because of the improved site stability and reduced gas explosion risk achieved. It also reduces the potential for odours, and in certain situations, methane yield optimisation techniques can lead to a lower organic carbon content in the leachates.

The contaminants such as hydrogen sulphide and ammonia account for considerably less than 1% of the total volume biogas produced, so that its combustion leads to no significant air pollution.

3.3 Engineered Anaerobic Digestion Processes

3.3.1 Technical Status

i. Anaerobic Digestion

Engineered plants which anaerobically digest municipal waste are constrained by the fact that only the putrescible organic fraction, normally 10-30% by weight, is digestible. Thus costly separation and then hydrolysis of the putrescible matter into soluble form is necessary before the digestion process, for which there are several designs. Currently there are no full scale plants operating in Europe, although there are six pilot/demonstration plants under construction in France, Germany, Italy and the UK. Laboratory research also continues, the majority in the USA, although at a reduced level compared to the late 1970's. Also most waste anaerobic digestion research is now directed to agricultural wastes.

Considerable further understanding and improvements are required in the biochemistry and engineering of the process in order to:

- increase the metabolism performance so as to raise the yield and production rate of combustible gas per unit of waste feed;

- reduce the amount and/or treatment/disposal cost of effluent and sludge, possibly through re-use.