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14

Analysis of Waste Management Options for Used Paper

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ANALYSIS OF WASTE MANAGEMENT OPTIONS FOR USED PAPER

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1. INTRODUCTION

Waste paper[1] recycling has been increasing in many countries in recent years. In 1994, the global waste paper recovery rate[2] reached nearly 40%, compared with 33% in 1988. Historically, waste paper recycling has been driven mainly by resource endowments and cost considerations. Countries such as Germany, UK, and Japan which produce insufficient virgin fibre to meet demand have used high amounts of waste paper since the 1950s and 1960s. In some developing countries, for example, Taiwan, the Philippines and Indonesia, the domestic paper industry has developed on the basis of waste paper imports. This use of waste paper has been motivated by financial considerations as a way of reducing costs of production and raw materials. But in recent years, there have been numerous policy initiatives, mainly in developed countries, to increase paper recycling beyond market-induced levels. These have been driven mainly by concerns about solid waste volumes, although other presumed advantages such as resource and energy conservation are commonly emphasised.

Such policies have had a significant impact on pulp and paper markets and questions are now being raised as to how much further paper recycling should go. While some groups stress the environmental advantages of recycling, concerns are also being expressed about the costs involved in collection and sorting, the effects on paper quality and the environmental impacts of de-inking.

The aim of this substudy is to examine the options for use or disposal of waste paper and consider their economic, social and environmental implications. It is structured in the following way:

- Section 2 gives a brief overview of current trends in recycling and disposal of paper.
- Section 3 reviews the evidence on life cycle comparisons of the environmental effects of paper recycling, incineration with energy recovery and landfill.
- Section 4 looks at the social factors associated with recycling and waste such as employment generation and the NIMBY factor.
- Section 5 examines the estimates available on relative costs of paper recycling and disposal.
- Section 6 reviews monetary estimates of the external costs of waste disposal.

Although the principal focus of the sub-study is on paper, much of the literature on recycling, in particular on the costs and social impacts addresses waste or recyclables in general. This reflects the fact that the main focus of attention is on paper waste generated by households. This is largely recycled and/or disposed of as part of schemes involving several types of material. We

[1] The term "recovered paper" is starting to replace "waste paper" in international statistics on recycling eg: FAO, as it better reflects the nature of this material. We use the term waste paper here because it is in popular usage, and because the chapter discusses the fate of waste paper that is not recovered as well as that which goes to recycling.

[2] Waste paper consumption as a percentage of total paper and paperboard consumption.

review this information as it nevertheless provides useful data for assessing the merits of different options for paper.

2. CURRENT LEVELS OF PAPER RECYCLING AND DISPOSAL

Paper products account for a significant proportion of municipal solid waste (MSW) in developed countries, e.g. 38% in the United States (EPA 1994) and between 30 and 40% in European countries (as shown in Table 2a). In developing countries, paper constitutes a much smaller proportion of the waste stream, reflecting lower consumption levels.

Table 2a: Total Amount of Paper and Paper Products in Waste Stream (1000 tonnes)

1000 tonnes	1975		1990	
	000 tonnes	% of total waste	000 tonnes	% of total waste
North America				
Canada	4662	37	6400	40
USA	5508	34	67450	38
Western Europe				
Austria	379	27	551	22
Belgium	870	30	1023	30
Denmark	716	35	534	22
Finland	1000	40	1147	37
France	5015	35	5738	31
Germany	5105	25	3810	18
Greece	500	20	660	22
Italy	2819	20	4407	22
Netherlands	1622	23	1857	25
Norway	527	31	620	31
Portugal	397	19	634	25
Spain	1204	15	2509	20
Sweden	1032	43	1408	44
Switzerland	570	30	930	31
UK	4800	30	7400	37
Eastern Europe				
Czech Republic			260	10
Hungary			1078	22
Poland			1280	10
Asia				
Japan	13075	31	19167	38

Source: OECD Environmental Data 1993

RECOVERY RATES

In 1993, the highest rates of recovery were in Western Europe (where several countries exceeded 50%), Japan and Taiwan. The largest growth in waste paper recovery rates over the last 5 years has been in North America and Western Europe. In contrast, some parts of Asia and Latin America have been experiencing declines in the waste paper recovery rate, suggesting that consumption has been growing faster than collection, see Table 2b below.

Table 2b: Waste Paper Recovery Rates

	Waste Paper Recovery Rate (%)	
	1988	1993
Western Europe	34.46	41.90
Germany	43.02	55.68
The Netherlands	53.57	54.89
Sweden	47.29	50.43
Austria	46.72	68.45
Switzerland	44.75	54.66
North America	29.78	39.62
United States	30.30	39.64
Asia	41.14	37.19
Japan	47.30	51.57
Taiwan	61.48	53.81
Latin America	33.63	33.22
Brazil	37.49	38.34
Chile	44.13	42.16
Columbia	44.53	39.19
Mexico	37.48	37.73
Oceania	27.55	31.75
Australia	27.51	34.69
Africa	22.99	26.47
South Africa	31.62	35.39
Eastern Europe	33.26	24.06
Czech Republic	-	26.74
Poland	35.22	35.47
World	33.92	38.24

Source: Calculated from Pulp and Paper International 1995

UTILISATION RATES

The global utilisation[3] rate of waste paper in 1993 was 38%. Figures for individual regions are shown in the table below together with countries with particularly high utilisation rates.

It can be seen that utilisation rates at the regional level are highest in Asia and Latin America. However, some countries within Europe such as Ireland and the Netherlands have rates in excess of 70%. It can also be seen that utilisation rates do not generally match recovery rates, indicating the importance of trade in waste paper.

[3] Waste paper consumption as a percentage of paper production. Figures can exceed 100% because some fibre is lost in the recycling process.

Table 2c: Waste Paper Utilisation Rates 1993

	Utilisation Rate
Asia	49.93
Japan	53.46
Korea Republic	68.97
Singapore	115.79
Latin America	49.44
Western Europe	38.23
Germany	53.67
Greece	70.18
Ireland	97.22
Netherlands	70.65
Spain	70.61
United Kingdom	60.05
Africa	37.71
Oceania	35.22
Australia	44.58
North America	32.78
United States of America	35.57
Eastern Europe	26.38
Croatia	70.00
Hungary	90.41
World	39.72

Source: Calculated from Pulp and Paper International 1995

Disposal of Waste Paper

Conventional Approaches

Landfill is still the predominant form of disposal for MSW in developed countries, although this is likely to change in the future. Incineration is an important disposal route for Japan (74%) and some countries in Western Europe, but is relatively rare elsewhere. There has been some increase in its importance in recent years but expansion has been impeded by local community and central government concerns. Sweden, for example, declared a moratorium on incineration in 1985 but lifted it some years later. In the United States, despite significant expansion in the 1980s, only 16% of MSW is currently incinerated (EPA 1994).

Incineration facilities vary considerably in terms of their age, technological sophistication and environmental performance. It was only in the late 1980s that incineration was recognised as a potentially valuable source of energy as well as a waste disposal option. Since then, virtually all new incineration plants have integrated energy recovery as a key component of schemes, and now it is often a prime consideration in the siting of new facilities. However, due to the ongoing operation of many plants originally built in the 1970s and 1980s without energy recovery, this is still the predominant type in operation in countries such as the UK (IIED Phase 1 Report 1995). This is likely to change in the EU when the directive on MSW incinerators comes into force, as many old plants will be closed down.

Other Options

Other options such as composting or anaerobic digestion[4] are rare, usually accounting for less than 4% of waste. There has been increasing interest in Europe and in the United States in the composting of organic waste but the extent to which paper is included in the schemes is limited (White, Franke and Hindle 1995, Franklin Associates 1994). Other combustion options such as refuse-derived fuel or paper-derived fuel, which involve pelletisation of waste or waste paper for use in industrial boilers, are also rare but may be on the increase. The current market in the US, for example is estimated at 0.5-0.75 million tons (Galeano 1995) a tiny fraction of the 78mn tons of paper in the waste stream. This is negligible when compared with the total size of the paper waste stream in MSW estimated at 78mn tonnes in 1993 (EPA 1994). Considerable expansion to 4mn tons by 2000 is expected but even so this will still be an option of minor significance (Galeano 1995, Raytheon Engineers 1993).

Developing Countries

The situation is very different in most developing countries. Waste disposal facilities are rarely capable of dealing with the volume of waste and a sizeable proportion is simply deposited in uncontrolled landfills or open dumps. In Mexico, official figures indicate that in 1990 only 21% of municipal solid waste was disposed of in authorised landfills (Secretariat for Social Development 1992). This suggests a greater urgency for improved waste management and possibly recycling in these countries. However, waste paper that is not recycled does not necessarily get thrown away immediately. In some poorer countries, paper products are reused several times for other purposes, e.g. as packaging or wrapping paper (IIED Workshop 1 1995). The scope for increased collection of waste paper in these countries may therefore be limited and there is a trade-off involved for particular sections of the population which reuse waste paper.

3. ENVIRONMENTAL COMPARISONS OF RECYCLING AND DISPOSAL OF PAPER

The main approach taken is to examine the environmental burdens of a given amount of paper under different assumptions about the extent of secondary fibre used in production and the destination of paper after consumption. The key feature of these life cycle analyses (LCA) is that they examine environmental impacts of a product, process or activity from "cradle to grave" i.e. at all stages of the life cycle, from raw materials extraction through to waste disposal and/or recycling. The first stage is to draw up a life cycle inventory which identifies and quantifies the emissions and resource consumption at each stage of the cycle. This is followed by an assessment of the significance of the various environmental impacts.

Life cycle analyses comparing paper recycling with disposal have concentrated on incineration with energy recovery as the main alternative. Some consider landfill as well as or instead of incineration. None of the studies identified consider other forms of disposal such as composting and biogasification in the comparisons. In the sections that follow the findings from seven LCAs listed below are reviewed:

[4] Anaerobic digestion or biogasification, like composting is a method of biologically degrading waste material. The main difference from composting is that it is carried out in the absence of oxygen.

- Recycle or Incinerate. The future for used newspapers: an independent evaluation
  1995 British Newsprint Manufacturers Association

- Paper Task Force Recommendations for Purchasing and Using Environmentally Preferable Paper Final Report
  1995 Environmental Defense Fund

- Ecological Balances as an Instrument for the Evaluation of Waste Management Alternatives
  1993 Prepared by Institut für Energie und Umweltforschung (IFEU) for the Commission of the European Communities

- A Life Cycle Assessment of Incineration or Recycling Waste Paper
  1993 Johnson C, MSc dissertation Imperial College of Science Technology and Medicine, London

- Life Cycle Analysis of Newsprint
  1993 Kärna A, Engstrom K and Kutinlahti T, Finnish Pulp and Paper Research Institute (KCL), Espoo, Finland

- Life Cycle Scenarios of Paper
  1995 Kärna A and Pajula T, Finnish Pulp and Paper Research institute (KCL), Finland

- Environmental Impacts of Waste Paper Recycling
  1993 Virtanen Y and Nilsson S, International Institute for Applied Systems Analysis, Earthscan, London, UK.

There are differences between these studies in the type of paper grade examined, the location of study and the scenarios compared. These are set out in Table 3a. Nevertheless, in most of the studies the aim is to compare high levels of paper recycling with high levels of landfilling of paper or with high levels of paper incineration. Although the percentages of recycling and alternatives differ, the comparisons being made are broadly similar.

Table3a: Life Cycle Studies comparing Paper Recycling with Disposal

Study	Paper Grade	Location	Scenarios
BNMA 1995	Newsprint	UK	Current technology 1. Base case: production with 74% recycled content. Disposal: 72% landfill;20% recycling; 8% incineration 2. 50% recycled 50% landfilled 3. 50% landfilled 50% incinerated Best Available Technology 1. Base case: production with 100% recycled content. disposal same as for current technology 2. 50% landfill 50% recycling 3. 50% landfill 50% incineration 4. 30% landfill 70% recycling 5. 30% landfill 70% incineration
EDF 1995	Newsprint Office Paper Corrugated boxes Coated Unbleached paperboard Solid bleached sulphate boxboard	US	1.Production with 100% virgin fibre and disposal to landfill 2. Production with 100% virgin fibre and dispoal to incineration 3. Production with 100% recycled content followed by recycling.
Johnson 1993	Newsprint	Consumption in UK Production in UK and Scandinavia	1. Production; 100% recycled content; Disposal: 100% recycling 2. Production in UK with 100% virgin fibre; Disposal: 100% energy recovery 3. Production in Scandinavia with 100% virgin fibre: Disposal: 100% energy recovery
Karna et al 1993	Newsprint	Consumption in Germany. Production in Germany, Finland and North	1. Reference case: Production: 63% with Finnish newsprint made from virgin fibre 37% made locally with 60% recycled content. Disposal: 60% landfilled 40% recycled. 2. Disposal: 20% landfill 80% recycled

Study	Paper Grade	Location	Scenarios
		America	3. Disposal: 40% recycling 40% burned for heat recovery.
Karna and Pajula 1995	All main grades of paper and board	Consumption in Germany. Production in Germany and Finland	1. Base case: 40% recycled 60% landfilled 2. 52.9% recycled 47.1% landfilled 3. 40% recycling, 47.1% landfilled, 12.9% for energy recovery
IFEU 1993	Newsprint	Consumption in UK Production in UK and Sweden	1a Production in UK of 100% recycled newsprint made from newspapers/magazines collected in UK. 1b Production in Sweden of 100% recycled newsprint made from newspapers/magazines collected in UK 2a. Production in UK of 100% virgin newsprint; disposal: incineration in UKwith heat recovery and power generation 2b. Production in Sweden of 100% virgin newsprint; disposal: incineration in UK with heat recovery and power generation.
Virtanen and Nilsson 1993	Main paper grades	Central Europe and Scandinavia	1. Maximum recycling - collection sufficient to give 56% furnish share. Of remaining paper 26% incinerated, 74% landfilled. 2. Selective recycling - Overall furnish share 35%. Of remaining paper 26% incinerate, 74% landfilled 3. Zero recycling and 100% incineration with energy recovery

In the sections that follow these studies are reviewed and key differences in assumptions and parameter selection are highlighted.

Recycling vs Incineration with Energy Recovery

Some of the studies (e.g. Johnson 1993, Kärna *et al.* 1993, Kärna and Pajula 1995, Virtanen and Nilsson 1993) conclude that in some circumstances incineration with energy recovery offers environmental advantages over paper recycling. Others (e.g. BNMA 1995, which examines newsprint in the UK, and EDF 1995, which covers five paper grades including newsprint in the United States) conclude that recycling is the environmentally preferred option[5].

Energy and Greenhouse Gas Emissions

Newsprint:
Of the five studies examining newsprint, all but one find that total energy requirements under a recycling scenario are lower. However, only two find that a high recycling scenario can result in lower greenhouse gas emissions. Location is also important, reflecting differences in production technology. One study (IFEU 1993) which compares recycling and incineration scenarios for the UK finds that recycling results in lower emissions of greenhouse gases if production is assumed to take place in the UK. If instead production is assumed to take place in Sweden, then the incineration scenario results in lower emissions.

Other paper products
The three studies examining other types of paper products or paper grades in general find that greenhouse gas emissions under a recycling scenario are higher than under an incineration scenario.

This outcome reflects the type of energy used in production based on virgin pulp as compared with recycled pulp. Recycling has a lower energy requirement but is likely to involve greater external inputs of fossil fuel energy. This is particularly the case where the comparison is made with the use of virgin fibre in an integrated facility, where excess energy from the pulping process can be used in paper-making, or in chemical pulping, where cooking-liquor and wood residues can be used as fuel. As virgin fibre based newsprint is generally made from mechanical pulp it requires a high external energy input which can often be fossil fuel-based. This explains why the recycling scenario for newsprint in some studies results in lower greenhouse gas emissions.

At the same time, incineration with energy recovery is likely to displace fossil fuel energy, which is more polluting. This is supported by other studies which show that emissions of SO_2, NO_x and particulates from incineration are comparable with, and in many cases lower than, those from conventional electricity generation based on fossil fuels (Egdall 1991, Royal Commission UK 1993, Astrand 1992, Svedberg 1993).

[5] In the case of the BNMA study this conclusion holds for the global scenario based on Best Available Technology. With current technology the study concludes that there is no clear winner in the comparison between recycling and incineration.

Air Pollution

Most of the studies make estimates for SO_2 and NO_X and some also look at VOCs and particulates.

Newsprint
Results from the available studies are mixed. Three studies find lower emissions of NO_X under a recycling scenario but these are not always accompanied by lower emissions of SO_2. The technology used in recycling appears to be a decisive factor. In the BNMA study, the switch to best available technology for recycling (involving more use of natural gas) results in lower emissions of SO_2 under a high recycling scenario. VOCs are found to be lower under the recycling scenario for newsprint in all cases except in the study by Johnson (1993).

Other types of paper
SO_2 is higher under a recycling scenario for all the cases examined. For NO_X emissions the situation is less clear and the outcome appears to depend on the type of paper product. For two types of product, office paper and bleached sulphate boxboard, emissions of NO_X are lower under a recycling scenario. For other types of air pollutant such as VOCs and particulates, the EDF study of different types of paper products finds that they are lower under a recycling scenario. In contrast, the study of all paper grades by Kärna and Pajula finds very little difference between the scenarios for VOC emissions because these largely occur in printing which is not really affected by the scenarios.

Water Pollution

Water consumption is considered by only one of the studies (Johnson 1993) which finds that it is slightly lower under an incineration scenario because of avoided energy inputs.

Newsprint:
Results are variable. For example, the EDF study finds higher emissions of BOD and suspended solids under a recycling scenario but lower emissions of COD.

Other types of paper:
Emissions of BOD and COD are generally lower under a recycling scenario. The exception is the study by Virtanen and Nilsson (1993) which finds that BOD is higher although COD is lower, an outcome for which there appears to be no plausible explanation.

Solid Waste

Results for solid waste are affected by boundary definitions and the distinction made between different types of waste. Thus it is difficult to draw any general conclusions. EDF 1995 makes no distinction between different types of waste and finds that for all the products examined except SBS paperboard, waste generation is higher under the recycling scenario. Kärna *et al.* 1993 distinguish between MSW and industrial solid waste and find that the latter is higher under a recycling scenario. This is because deinking sludge is found to be greater in volume than incinerator ash or because wastes from energy extraction are included. BNMA (1995) makes a distinction between hazardous waste and solid waste (which includes MSW and industrial solid waste). It finds that hazardous waste increases under an incineration scenario because of the

heavy metal content in gas cleaning residues and flyash. Solid wastes are also found to be lower. This may reflect the assumption made in this study that 70% of deinking sludge is landspread.

Table 3b summarises the results of the studies for newsprint. For selected parameters the table shows whether environmental releases under a scenario with high levels of recycling are found by each LCA to be higher than (H), lower than (L), or the same (S) as under a scenario where most waste newspaper is incinerated. Table 3c provides the same type of comparison for LCAs of other paper grades.

Table 3b Environmental Releases under a Recycling Scenario for Newsprint compared with an Incineration Scenario

Study	Total Energy	Fossil Energy	Net CO_2 Equivalents	SO_2	NO_x	BOD	COD
BNMA 1995							
a) Current technology	H	n/a	H	H	L	L	L
b) Best Available Technology	L	n/a	H	L	L	L	L
Kärna *et al.* 1993	n/a	n/a	H	H	L	n/a	S
EDF 1995	L	L	L	L	L	H	L
Johnson 1993							
a) Production UK	L	n/a	H	L	H	H	H
b) Production Scandinavia		H	H	H	H	H	H
IFEU 1993							
a) Production UK	L	L	L	n/a	n/a	n/a	n/a
b) Production Sweden	L	H	H	n/a	n/a	n/a	n/a

L, H, S : Lower, higher or same emissions/use under the recycling scenario as compared with an incineration scenario.

Table 3c Environmental Releases under a Recycling Scenario for Various Paper Products compared with an Incineration Scenario

Study Paper grade	Total energy	Fossil Energy	Net CO_2 Equivalents	SO_2	NO_x	BOD	COD
EDF 1995							
a) Office paper	L	H	H	H	L	S	L
b) Corrugated boxes	L	H	H	H	H	L	n/a
c) Coated unbleached kraft paperboard	L	H	H	H	H	L	L
d) Solid bleached sulphate boxboard	L	H	H	H	L	L	L
Kärna & Pajula 1995							
All main grades	n/a	n/a	H	H	S	L	n/a
Virtanen & Nilsson 1993							
All main grades	L	H	H[1]	H	H	H	L

L, H, S : Lower, higher or same emissions/use under the recycling scenario as compared with an incineration scenario.

[1] Does not include methane

It can be seen that in most cases a recycling scenario will result in lower total energy use. There will, however, be greater use of fossil energy and greater emissions of net CO_2 equivalents[6].

For other air and water emissions the results are much more variable and no clear picture emerges. The two studies that favour recycling base their argument more on changes in air and water pollution releases. The studies that favour incineration put more emphasis on reductions in global warming equivalents.

[6] Most of the studies distinguish between fossil fuel CO_2 emissions and biomass CO_2 emissions. The latter are considered neutral as they offset carbon uptake at an earlier stage.

Recycling vs Landfill

Some of the studies compare scenarios involving different combinations of recycling with landfill. They mostly indicate that recycling is preferable as shown in Table 3d. There is some variation in results reflecting differing assumptions about carbon uptake and biodegradation in forests and in landfills. The BNMA study finds that increasing recycling at the expense of landfill reduces most key environmental releases but results in higher emissions of global warming equivalents even with best available technology. In contrast, the EDF study concludes that for five types of paper product, a scenario based on 100% recycling results in lower emissions of global warming equivalents than a 100% virgin production and landfilling scenario. Emissions of most air pollutants and some water pollutants[7] are also found to be lower under the recycling scenario.

Table 3d Environmental Releases under a Recycling Scenario for Various Paper Products Compared with a Landfilling Scenario

Study	Total Energy	Fossil Energy	Net CO_2 Equivalents	SO_2	NO_x	BOD	COD
BNMA 1995							
a) Current technology	H	n/a	H	H	L	L	L
b) Best Available Technology	L	n/a	H	L	L	L	L
Kärna *et al.* 1993	n/a	n/a	L	H	S	n/a	L
EDF 1995							
Newsprint	L	L	L	L	L	H	L
Office paper	L	H	L	L	L	S	L
Corr. boxes	L	H	L	H	L	L	N/A
CUK paperboard	L	H	L	S	L	L	L
SBS boxboard	L	H	L	L	L	L	L

L, H, S : Lower, higher or same emissions/use under the recycling scenario as compared with a landfilling scenario.

Landfill vs Incineration

Only two of the studies explicitly compare the environmental impacts of landfill and incineration as destinations for waste paper. Their results are shown in Table 3e. The EDF study does not include the impact of leachate from landfills but indicates nevertheless that incineration is preferable to landfill as a destination for waste paper. With the BNMA study it is difficult to draw a firm conclusion on this comparison.

[7] The EDF LCAs do not include waterborne waste caused by leachate from landfills.

Table 3e Environmental Releases under a Landfilling Scenario for Various Paper Products Compared with an Incineration Scenario

Study	Total Energy	Fossil Energy	Net CO_2 Equivalents	SO_2	NO_x	BOD	COD
BNMA 1995							
b) Best Available Technology	H	n/a	L	S	L	H	H
EDF 1995							
Newsprint	H	H	H	H	H	S	S
Office paper	H	H	H	H	H	S	S
Corr. boxes	H	H	H	H	H	S	n/a
CUK paperboard	H	H	H	H	H	S	S
SBS boxboard	H	H	H	H	H	S	S

L, H, S : Lower, higher or same emissions/use under the landfilling scenario as compared with an incineratio scenario.

Conclusions Drawn from the Life Cycle Studies

Most of the studies support the view that recycling is environmentally preferable to landfill. There is less agreement on whether recycling is preferable to incineration. Critical factors are the nature of the pulp and paper-making process, the level of technology at all stages of the life cycle and the energy structure of the countries under study. Interpretation also plays a role in the weighing up of increases in some emissions against reductions in others. There has been somewhat less attention to comparisons between landfill and incineration and the two studies reviewed give different results. A further LCA carried out in Germany as part of IIED Sub-Study No. 15 examines the effect of replacing landfill as a disposal route for waste paper by incineration. The results indicate reduced emissions of methane and water pollutants but some increases in emissions of air pollutants.

Drawbacks of LCAs

Most of the LCA studies avoid the issue of forest management. Fibre production is either left out or assumed to be sustainable, so that lower levels of wood consumption under a recycling scenario are not considered a benefit. This highlights the main drawback of most LCAs, i.e. that they often do not take account of more dynamic linkages. The EDF study, while not including wood consumption in the life cycle inventory, argues that recycling will extend the virgin fibre base and thus reduce the overall intensity of forest management required to meet a given demand for paper. It can "thus help to foster changes in forest management practices that are environmentally beneficial" (EDF 1995). The problem is that it is difficult to prove this complex relationship and alternative interpretations are possible. Virtanen and Nilsson (1993) argue that increased recycling could have a detrimental effect on forest quality as it would reduce

the demand for thinnings. This would adversely affect incentives to carry out management practices that they consider essential for sustainable forests.

A further disadvantage of most LCAs is that they can only look at a limited number of measurable parameters - for example, the environmental impacts of hydroelectric power or of nuclear power are not considered. Also, less tangible impacts associated with incineration and landfill, such as traffic congestion and noise or visual aesthetics, cannot be addressed easily in this type of analysis.

Shortcomings of LCAs - Landfilling

Some of the studies leave out aspects of landfill impact. For example, the EDF analyses exclude the effect of leachate. This reflects the difficulties involved in estimating leachate generation and leakage. A number of factors such as the type of liner, the geology of the site and the efficiency of the collection system will affect the leakage rate, and there is a lack of reliable data (White, Franke and Hindle 1995). There is some evidence also that landfills are sources of dioxin emissions through combustion of landfill gas or through spontaneous fires, and such emissions are not estimated in the LCAs (Zeschmar undated, Rappe 1995). Nevertheless, recognition of these omissions tends to reinforce the conclusions of the LCAs that recycling and incineration are preferable to landfill as a destination for waste paper. However, one area which may affect the conclusions is the rate of carbon decomposition in landfilled paper. There is considerable uncertainty over this given the long time spans involved.

Shortcomings of LCAs - Incineration

Variation in Emissions: LCA comparisons tend to be made for modern incinerators. But emissions from incineration can vary considerably depending on the age of the facility and the extent of gas cleaning. This reflects the fact that MSW incineration has in the past been little regulated. For example, in the United States until 1991, particulates were the only incinerator pollutant subject to control (Steverson 1994). Table 3f shows typical emission levels from incinerators in various countries. It can be seen that there is considerable variation, implying that it will be some time before all incinerators achieve equally low levels of emissions. In the EU, where new standards for MSW incinerators are coming into force, considerable improvement can be expected. Nevertheless, these new standards are considerably less strict than current standards in Germany and the Netherlands and a further directive with more stringent standards is under discussion (Veiga-Pestana 1994).

Table 3f Typical Emission Levels from Incineration

Pollutant mg/m^3	UK	Sweden		Canada	Germany
	(range)	Older plant (range)	Modern plant		
Particulates	16-2800	1-90	1.2	-	15
CO	6-640	-	-	-	-
HCl	345-950	450-900	25	-	_2
SO_2	180-670	90-360	17	-	-
HF	-	4.5-9	_2	-	-
NO_x	-	180-360	-	-	-
Pb	0.1-50	0.45-2.7	0.06	0.055	0.358
Cd	_0.1-3.5	0.045-0.9	0.002	0.004	0.026
Hg	0.21-0.39	0.27-0.36	0.09	0.02	0.067
TCDD ngm^{-3}	0.73-1215	4.5-90	0.04	0.0	-
TCDF ngm^{-3}	6.84-1425	-	-	0.1	-
PAH μgm^{-3}	-	0.9-90	-	0.1	-

Source: Williams 1994

Dioxins and Furans: A further concern is that emissions of chlorinated organics such as dioxin (PCDD) and furans (PCDF) are not included in the LCAs. This reflects the fact that these types of emissions are not easily related to specific waste streams (Aumônnier 1995). Human exposure to dioxins may be through ingestion of food, inhalation and skin contact (Department of Environment 1989). Recent assessments have indicated that the main exposure route is through the food chain and that inhalation is relatively insignificant (EPA 1994a, ECETOC 1992). Aerial deposition of dixoins onto soil, water and plants results in dioxin accumulation in the tissues of grazing animals or fish.

Many experts argue that dioxin emissions from modern incinerators are now too low to present any significant risk, pointing out that dioxins in the incoming feedstock are largely destroyed by the incineration process (White, Franke and Hindle 1995, Porteous 1996). However, concerns are raised about cumulative effects and potential carcinogenic and reprotoxic effects of low-level emissions. Those concerned about dioxin emissions argue that human body burdens are already too close to the acceptable limit and that any further emissions, however small, can only have a damaging effect (Webster and Commoner 1994).

The uncertainty over the human health effects of dioxin intake is evidenced by the difference in emission limits for incineration and by the differen tapproaches to establishing acceptable daily intakes. The draft EC directive proposes a limit of 0.1 ng TEQ/Nm^3 in line with existing limits in Germany and Sweden while the UK as the same guide value but a somewhat higher limit at 1.0 ng TEQ/Nm^3. The discussed standard in the US is an emission counted in total PCDDs and PCDFs as 30 ng/m^3 which corresponds to about 0.45 ng TEQ/m^3 (Rappe pers. comm 1996). In the US, the acceptable daily intake is 6 fg TCDD/kg body wt/day based on a linear dose

response function, while the WHO sets a significantly higher limit of 10pg TCDD/kg body wt/day based on a threshold concept of no observed adverse effect decreased by application of a safety factor (WHO 1991).

The recent US EPA draft dioxin reassessment gave added prominence to this debate, as it pointed to municipal incineration as a significant source of dioxins in the United States, reaffirmed the carcinogenic nature of dioxins and emphasised the importance of non-cancer related health effects (Environmental Science and Technology 1995). As discussed in Chapter 8 of the main report, the reassessment was a draft for review and has been the subject of much criticism and debate.

Rappe (1995) criticises the reassessment for overemphasising the contribution of incineration by not including other significant sources of dioxins, such as emissions from earlier application of pentachlorophenol (PCP) for wood treatment, the iron and steel industry and landfill fires. He argues that PCP, even though now banned in many countries, could still be the largest source of dioxins. He cites studies which indicate that dioxin levels in humans, animals and vegetation increased dramatically during the 1960s and 1970s but declined significantly thereafter. Rappe attributes the dramatic increase to use of PCP and points out that declines in dioxin levels took place in a period when numerous incineration facilities were being put into operation. He also cites evidence that dioxins can arise from natural sources, in particular as a result of enzymatic reactions in composting.

Concerns are also raised over the potentially high dioxin and heavy metal content in the flyash of incinerators. The flyash has to be disposed of in special landfills and there are possibilities of leaching (RCEP 1993). Regulatory attention has now shifted to this issue and a number of technological options are available. In Germany, new facilities will require treatment of flyash to eliminate the risk of leaching of heavy metals when landfilled (Scutter and Dyke 1994). The proposed EC directive also sets strict limit values for ash concentration. Technologies such as vitrification and thermal detoxification (maintenance of high temperatures with low oxygen levels) have been shown to reduce dioxin concentrations significantly (Eduljee 1995). An alternative approach which has been used in an incinerator in Vienna, is to use a de-NO_x catalyst as a flue gas cleaning device. Through oxidation the dioxins are converted to CO_2, HCl and water (Rappe pers. comm.).

A key issue, particularly where incinerators are not state of the art, is the extent to which paper contributes to the emissions of dioxins and heavy metals. Because of its chlorine content PVC is widely claimed to be the main contributor to dioxin and furan emissions, while paper is thought to contribute if it is bleached with chlorine or printed with certain types of inks. But incinerator trials have provided evidence that the relationship is not so straightforward (Shaub 1995, Visalli 1987). Research by Marklund *et al.* (1994) has shown that where paper is incinerated on its own, even if it is bleached with chlorine or with a high heavy metal content, there is a minimal effect on dioxin generation. Comparisons were made of emissions from incineration (without any air pollution control device) of unbleached and bleached paper packaging, paper packaging with aluminium foil and/or with printing ink containing a small amount of copper. The study also compared emissions from paper-based packaging with those from municipal solid waste and found that they were significantly lower in the former case. Another important finding was that increasing the copper content by a factor of 30 had little effect on emissions, even though this is believed to act as a catalyst in the post-combustion

formation of dioxins. This research suggests that combustion of paper on its own could be an environmentally safe option even without extensive emissions control devices.

The extent to which paper contributes to dioxin emissions from mixed MSW is less clear, reflecting uncertainty over the main mechanisms for dioxin formation. A number of formation routes for dioxins and furans have been identified and researchers differ in the emphasis which they give to each of these. Some argue that the most important factor is the dioxin and furan content in the incoming waste, in which case paper would be unlikely to contribute. Others emphasise mechanisms such as reactions of carbon, hydrogen, oxygen and chlorine in the post-combustion stage. The key requirements would be an oxygen-rich environment, a source of chlorine - which can include inorganic chlorides such as sodium chloride (i.e. kitchen salt) - and the presence in the flyash of a metal catalyst, typically copper. It is for this reason that many of the same organic compounds have been detected in almost all stack gas samples, irrespective of the waste feed or type of combustor (Eduljee 1995). As some of these elements are present in paper, this would suggest that, in combination with other elements of MSW, it could in theory lead to the reactions described above.

4. SOCIAL COMPARISONS OF RECYCLING AND WASTE DISPOSAL

Social Benefits of Recycling

Two social benefits of recycling are commonly asserted. The first is the fact that recycling results in people "feeling good"; a sense of satisfaction is felt by them at making a valuable contribution to the protection of the environment. The second more concrete social benefit is the fact that recycling may result in higher employment levels in the community in which it is undertaken.

Public Acceptance of Recycling and the "Feel Good" Factor

Evidence of the public's posititve attitude to recycling is given by the high level of participation in some recycling schemes. One such scheme is a kerbside operation that is being run in Adur (UK). The scheme is supported by the European Recycling and Recovery Association (ERRA) who estimated that participation in the scheme was around 68%. A similar figure is anticipated by ERRA for the other schemes that they support in Europe. ERRA also believe that the appropriateness of the recycling scheme is important in achieving high participation. They state that, of the schemes that they are involved in, kerbside "box" schemes tend to work the best in terms of participation. They put this down to the high visibility of the box and householder pride in putting out a full box of clean recyclables (ERRA, 1994).

High levels of participation have also been recorded in surveys undertaken by the Civic Amenity Waste Disposal Project (CAWDP) of participation in kerbside schemes in operation in Stocksbridge, Luton and Milton Keynes. Participation rates in each of these places were 67%, 63% and 58% respectively (Coggins, 1993).

Surveys of attitudes to recycling in the UK also show that many people are supportive of the idea. According to one survey, over 90% of non manual workers and retired people and 65% of manual workers believe that it is essential that everyone tries to recycle as much as possible

(ibid). Another survey conducted by CAWDP asked non-recyclers in Sheffield why they do not recycle. Inconvenience associated with lack of recycling facilities was found to be the primary reason. Only a small number said they were not interested in recycling (ibid).

In the US, surveys carried out by the National Solid Wastes Management Association indicate that most Americans want to recycle and are willing to pay for it (Miller 1993). A survey carried out in Washington State found that the public considered recycling to be extremely important with an average rating of 6.45 on a 7 point scale and more important than other activities such as voting, reducing consumption and donating to charity (Hehnen 1994).

Employment

It is often claimed that recycling provides more jobs than other disposal options, or than paper-making based on virgin fibre. In the UK it has been claimed that a key aim of the recycling programmes introduced in London in the 1980s was the generation of employment (Gandy 1994). In developed countries the increased employment comes particularly in the area of collection and sorting of waste, as these tend to be fairly labour intensive processes. However, increased recycling can also result in more employment for waste merchants and dealers. In developing countries, increased recycling results in more jobs in the formal sector related to waste buying, selling, dealing and transporting, but a large proportion of employment related to the recycling industry is in the informal sector in waste picking or scavenging (Furedy 1992).

Formal Sector

Hard evidence on the employment implications of recycling in the formal sector is rather scanty and location specific. A study of newsprint recycling in the UK estimated that for each 1000 tonnes of newsprint, 12 jobs would be created from recycling compared with four jobs for incineration (BNMA 1995). This study estimated both direct employment effects in building and operating newsprint mills or incinerators and indirect effects on employment in other sectors resulting from increased demand for intermediate inputs or services. Building a modern newsprint mill of 300,000 tonnes capacity would yield more than 4000 new jobs while an incinerator of the same capacity would yield only 1,200.

Jerkeman (1993) of Jaakko Pöyry Consulting estimated the implications of an increase in recycling for employment in Sweden, Germany, Romania and the Philippines. For each of the countries, two scenarios up to 2005 were constructed, one with a low increase in recycled fibre consumption and one with a high increase. For Sweden and Germany, the lower recycling scenario was in line with what the industry claims is the technically and economically feasible level and the higher recycling scenario was in line with what "green groups" and politicians claim is necessary. For Romania and the Philippines the scenarios were more extreme with expansion to meet projected local demand based mainly on domestic virgin fibre in one scenario or imported waste paper in the other. The implications for employment of each of the scenarios are set out in Table 4a.

Table 4a Employment Effects of Increased Recycling

	Scenario 1 & 2	Waste Paper Consumption 2005 million tonnes	Increase in Employment
Sweden	1 "More virgin fibre"	1.5	7600
	2 "More recycled fibre"	3.0	4000
Germany	1 "53% utilisation rate"	10.1	5000
	2 "65% utilisation rate"	12.3	5000
Roumania	1 "Expansion - domestic pulp"	0.08	3400
	2 "Expansion - imported wp"	0.51	900
Philippines	1 "New Forests"	0.36	12200
	2 "Imported Waste"	0.81	1300

Source: FAO, 1994

It can be seen that expansion based on domestic virgin fibre gives higher employment in the countries concerned. The increased employment is mainly related to forestry, particularly in the Philippines. However, in all cases the expansion of waste paper use is based on imported material implying that employment in collection and processing may take place in other countries. Also, the permanence of job creation in plantation development has been questioned. High labour inputs are required initially to clear the land, construct infrastructure, and for planting and maintenance. In later years labour requirements may be lower (Barraclough and Ghimire 1990, Bass 1993).

Informal Sector

In developing countries, the volume of waste paper recovered may be small compared to that of developed countries. However, recycling can be an important source of employment for poorer groups of society. In social terms waste pickers are beset by numerous difficulties, eg extreme poverty, exploitation of children and oppressive living conditions and health problems. The latter are often caused by the types of wastes that waste pickers are in close contact with. For example in Bombay, India a high concentration of heavy industry means that toxic wastes contaminate most rubbish tips and many children suffer from TB, bronchitis, skin allergies and eye irritations and (because of low wages) malnutrition. (Warmer Bulletin, November 1993).

In addition to these difficulties, waste pickers face the additional problem of low social status. According to Furedy (1992) there is no societal recognition of the importance of waste recycling to the economy of many of developing countries, thus waste pickers have no concept of their work as being useful or worthy of regularization. This is illustrated by a survey of waste pickers in Calcutta summarised in Box 4a.

Box 4a Case Study of Street Pickers in Calcutta

In 1990 the United Bustee[1] Development Association (UBDA) carried out a survey of waste pickers in Calcutta. The survey was based on half hour interviews with pickers from two slum areas of the Calcutta metropolitan area: Tikiapara and Tiljala. The sample interviewed consisted of 29 people, 5 women and 24 men. The aim was to obtain information about city waste picking as an occupation, the pickers awareness of possible health hazards, their perceptions of their social status, how they were treated by the public and how they think others perceive them.

Results from the survey showed that pickers frequently suffered from backache, rheumatic pain and cuts which were likely to have occurred as a result of their job. However pickers were unaware of the infectious hazards associated with gathering waste. While many reported getting cuts while working none took precautions such as washing hands with soap after work to prevent infections. 62% did not favour the idea of wearing gloves, as a protectionary measure. The other 38% were however willing to experiment with gloves if provided free.

In terms of social status pickers were generally treated as outcastes. This results in difficulties such as lack of access to water sources because higher caste groups object to their using the local pumps and wells. Further, pickers suffered from harassment due to their work.

In addition, the pickers actually saw their work as being of low status. Only one thought that his work was of any value. In general respondents were dissatisfied with their occupation and did not want their children to be pickers.

[1] The word "bustee" is the Hindi term for "slum".

Source: Furedy 1992

Waste picking may be a particularly important income source for women. In Chile, for example, one NGO that works with informal waste paper recyclers reports that most of them are female heads of households (Orr 1995). Similarly, a study of waste pickers in Bangalore, India, found that a large proportion were women from low castes (Huysman 1994). Waste picking enabled them to combine their work with their household duties and other employment opportunities were very limited. However, they were at high risk of illness and infections and received very low prices for the material they obtained because of the intermediation system (see Box 4b).

Box 4b Case Study of Women Waste Pickers in Bangalore

It is estimated that there are 25000 waste pickers in Bangalore, a city with a population of 4.1 million. A large proportion of this total are women from low castes. A survey of the women was undertaken by Huysman between 1989-1990. The sample consisted of 161 women waste pickers who were all interviewed individually.

The survey revealed that the main reason for women taking up such work is their need to ensure a subsistence income. Opportunities in terms of other forms of employment are very limited for women of low caste in India. Further, wastepicking enables women to combine their aim of earning a living with their household duties. Thus while waste picking is not an occupation of choice, when other avenues and opportunities are lacking, it becomes an alternative.

The survey also found that the income earned by the women is very low. Wastepickers do not sell materials recovered, directly to a factory. Materials only reach the factory through a network of dealers and wholesalers. The waste pickers earnings are dependent on the price they obtain from dealers/wholesalers. Dealers tend to enlarge their profits by keeping prices low, and cheating waste pickers by undercounting when wastes are weighed or by binding them to him for long periods of time through loans and other facilities.

Together with low earning the women were found to have poor quality housing, unhygienic environments and a lack of access to education and medical care. Furthermore waste picking by women who were mothers appears to have a negative effect on their children. Only a small minority of the children attend school, instead they pick waste with their mothers.

Waste pickers were found to be daily exposed to illnesses and infections, which when combined with the fact that the women typically have inadequate washing facilities in slums and lack of access to medical care means that they are prone to serious health problems.

In terms of status the women are looked down on and treated as nuisances and a threat to the image of the city. Further they are often treated as thieves. As such it is not surprising that the wastepickers have very low self esteem.

Source: Huysman 1994

In many developing countries a number of organisations (usually non governmental) have set up community-based schemes to assist people whose livelihoods depend on wastes. in improving their earnings, health, living conditions and security (Furedy 1992). Some examples are given in Box 4c. These organisations accept the existence of informal activities in waste recovery and recycling and rather than seeking to replace them by formal schemes are looking for ways to improve the earnings, health, living conditions and security of the people concerned. As some countries are attempting to increase domestic waste paper recovery, there is concern that introduction of Western-style collection schemes will displace the informal paper collectors and undermine efforts to improve their living conditions.

Box 4c Examples of Organisations working with Waste Pickers

The Institute for Development Studies in Jakarta, Indonesia (Lembag Studi Pembangunan - LSP) encouraged the development of co-operatives of waste pickers and collectors in order to improve their bargaining power witlers. LSP is also involved in a development programme called "Scavengers in Indonesia". The aim of the programme is to set up projects in Jakarta, Surabaya and Bandung which will undertake research, education, community development, technical and business training and "political dialogue" to improve the productivity and status of waste pickers. The rationale for the programme is that waste pickers are shouldering some of the ecological costs of development by saving resources and reducing waste transportation and disposal costs.

The Garbage Recycling and Segregation Programme (GRASP) in Pune (India) is specifically targeted at women waste pickers. GRASP aims to improve the work circumstance and income of women by securing their access to waste that has been segregated at source from households. This has been done after presenting the waste pickers with information on the dangers of their original working practices and on the concept of source separation and recycling. After 18 months GRASP waste pickers have registered an increase in their income and have achieved shorter working days. In the future GRASP plans to have non formal education classes for the children of waste pickers, health services and the provision of short term credit. GRASP plans to develop a relevant and self sustainable economic system for waste pickers by establishing a series of cooperatives in waste materials, credit, production and marketing.

Ragpickers Education Development (RED), is particularly targeted at children. RED have set up a shelter, in which meals and schooling are provided, for street children involved in waste picking. RED has persuaded local companies to send their rubbish directly to the shelter so the children do not need to go out onto the street. The children now do not have to search for rubbish or compete with other pickers; this has enabled their earnings to go up significantly. Further RED works closely with another local charity called MAYA (Movement for Awareness of Youth Alternatives) which tackles the problem of making a future for the boys once they become too old to be waste pickers. MAYA negotiates with local employers to secure jobs for boys over 14.

Source: Furedy 1992 and Sasono 1988

SOCIAL COSTS OF WASTE DISPOSAL

The NIMBY Factor

Despite the developments in incineration technology and its increasing acceptance by many governments, there have been relatively few new waste-to-energy plants built in recent years in Europe and North America, mainly because of failure to obtain planning permission at a local level. Landfills have been similarly affected. In the United States it can take 2 to 7 years to find a site and get a permit for a landfill (Repetto *et al.* 1992). Much effort has been made to understand the basis for the so-called NIMBY factor ("not in my back yard") but there is still considerable disagreement. According to Petts (1994) the basis for this opposition is complex, and the expert view that public concern is based upon an irrational fear of the risks to health is overly simplistic. Other factors such as trust in regulatory authorities, the extent of information provision and decision-making processes are also important.

Public Attitudes to Risk

Studies have shown that perceived risks are greater for hazards whose adverse effects are considered to show the following characteristics:

- uncontrollable
- unfamiliar,
- fatal,
- delayed and therefore a threat to future generations,
- generated by man and not offset by direct compensating benefits.

For waste facilities in particular, studies indicate that the public's fear centres on:

- accidents which could harm residents (particularly where toxic wastes are involved)

- long term health impacts from emissions

- potential harm to children.

Where toxic or hazardous wastes are not to be handled then concerns appear to be less vociferous (Petts and Eduljee 1994).

Much research has been conducted into determining the reaction to risks by the general public. Studies indicate that the influence of friends, neighbours, and colleagues is important in determining attitudes towards risks (eg Douglas & Wildavsky 1982, in Petts and Eduljee 1994), as is class and education background (eg Prescott-Clarke 1982, in Petts and Eduljee 1994).

Also, media attention given to a particular landfill or incineration site can affect the public's attitude towards risk. Evidence of this comes from a study conducted by Chambers *et al.* (in Petts and Eduljee, 1994) which looked at the process of an incineration and landfill facility being used by Westinghouse Electric Corporation. There was a large amount of public opposition to the use of the facilities. As a result the EPA opened a Public Information Centre with a telephone hotline to monitor public attitudes and to disseminate all available information. Data were collected on hotline records and newspaper coverage to examine the correlation between newspaper coverage of local environmental news and public participation patterns. A positive correlation was found between the total number of local newspaper articles and the total number of activists hotline calls.

However, an important factor determining reaction to risk is "proximity" to the potentially risky activity. Armour (1991) after reviewing a number of studies stated that proximity is a factor determining people's attitudes to risk and that peoples "comfort zone" varies by type of facility and its perceived positive and negative externalities. These studies suggest that provided disposal facilities are located sufficiently far away from residential areas there would be little problem. Other researchers have stressed the importance of proximity to the main access routes to the incinerator or landfill/waste disposal facility, rather than to the facility itself (Furuseth 1990).

According to Petts and Eduljee (1994) NIMBYism is about more than just a fear of risks associated with health and safety. They describe it as being a problem of "trust and confidence, a problem of information provision and a problem of flawed siting decision processes". It is when these problems are understood that attempts can be made to deal with the problem of NIMBYism.

Problems of Trust

Portney (1991) in a study of disputes over the siting of hazardous waste facilities in the USA concluded that lack of trust was clearly evident but was primarily political in nature. As a result, the public was increasingly less willing to assess risks and to evaluate proposals for new facilities on their own merits. In relation to the UK where there has been increasing involvement of the private sector in waste management, Petts (1992) attributes lack of trust to the following factors:

- The public's concern that the private sector's drive for profits will lead to safety and environmental issues being given less attention.
- Concern that the drive for profits encourages operators to build facilities which are dependent on the import of wastes from other areas and countries (leading to certain communities having to bear a disproportionate share of the environmental and safety costs of such facilities).
- Lack of trust in operators to control site operations and to mitigate accidents.
- Lack of trust in regulatory authorities to monitor operations and to identify problems.
- Mistrust in the general state of knowledge about the risks from waste facilities and in particular from incinerator emissions.

To overcome the problem of trust, Petts and Eduljee (1994) make the following recommendations to restore the public's confidence:

- The public should be shown that appropriate regulations in relation to the facilities have been or will be introduced.
- It should be demonstrated that incineration and landfill sites are being or will be managed well.
- The industry's commitment to safe operation should be made clearly visible.

Problems of Information Provision

The main difficulty is one of inadequate, incomplete or uncertain information, and the lack of transmission of information. If sufficient information is provided in the right way then NIMBYism would be less likely to exist. Wiedemann and Femers (1991) identified the following types of information as essential for public dissemination:

- Technical aspects: safety systems, how the incinerator/landfill operates.

- Risks and benefits: health risks, new jobs created.

- Opportunities for participation: who will operate facility and how public can influence the decision.

- Need and alternatives: need for the facility, alternatives to it.

There is some evidence that community attitudes towards waste-to-energy plants can be influenced by the extent of consultation and information provided. Extensive public information campaigns in Sweden and France have improved public acceptance of energy from waste (Scutter and Dyke 1994).

Problems of Flawed Decision-making Processes

Until recently, the "decide-announce-defend" model has generally been used when siting an incineration or landfill facility. Key decisions related to the need for the facility, the type of technology, and the choice of site have been taken in isolation from those people who are likely to be most directly affected by the decisions. Such a top-down approach has (not surprisingly) often led to confrontation. As stated by Armour (1991) "Faced with a proposed change in their life circumstance that they neither initiated nor requested, local residents understandably resist. The top-down nature of facility siting naturally evokes a "why us" reaction". The public needs to be involved at an early stage in the process if a NIMBY response is to be avoided.

An alternative approach is to offer compensation to the local community in the form of employment, reduced waste disposal fees, or specific community amenities such as swimming pools. This has been a typical approach in Japan (IIED Sub-Study No. 16), while some waste management companies in the United States have also overcome community opposition in this way.

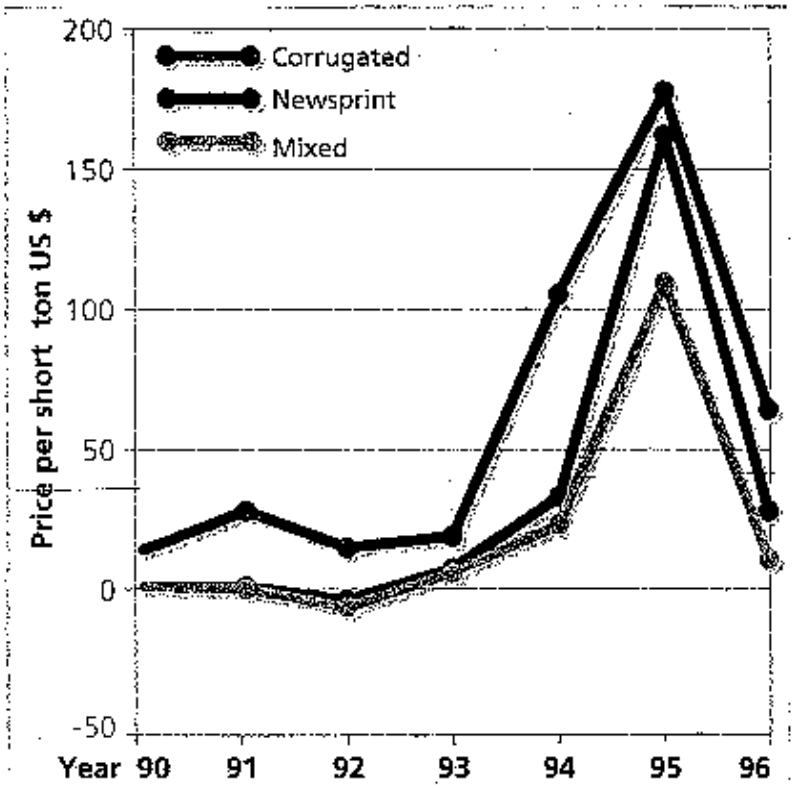
5. ECONOMIC COMPARISONS

PRODUCTION

Financial benefits from recycling waste paper can occur both in production and in waste disposal. Looking first at production, it is generally the case that capital and operating costs of de-inking and recycling plants are lower than for an equivalent scale virgin pulp mill. However, a key variable in the comparison is the price of waste paper, which can vary considerably. Historically, waste paper prices have followed substitute virgin pulp prices with a margin reflecting differences in quality and market acceptability of the final product. In the 1990s, fluctuations in waste paper prices have been accentuated by imbalances in supply and demand resulting from measures to promote recycling. Increased waste paper collection in Europe and North America coinciding with depressed virgin pulp prices led to sharp falls in waste paper prices, in some cases to negative levels, as supply outstripped available processing capacity. As more de-inking capacity came on-stream, accompanied by demand-focused policy measures, such as recycled content requirements, and as recycled content came to be seen as a marketing advantage, demand began to exceed supply and prices were forced up. Some grades of waste paper became more

expensive to use than equivalent pulp grades. Waste paper prices have since fallen (as indicated in Figure 5a) but not to the low levels prevailing in the early 1990s.

Figure 5a Waste Paper Prices in the United States



Source: PPI 1995 and Paper Recycler 1996.
All prices are for second quarter. Figure for 96 is for 1/2/96

Comparisons made by Jaakko Pöyry for the second quarter of 1995 when waste paper prices were extremely high, show that total delivered costs of recycled fibre newsprint in Western Europe were higher than for virgin fibre-based newsprint in Scandinavia. A large part of this difference was accounted for by the higher cost of recycled fibre. Comparisons for virgin fibre-based and recycled fibre-based linerboard in the United States gave a similar picture, with higher costs of fibre offsetting the savings in energy for recycled fibre linerboard (IIED Sub-Study No. 11).

Table 5a Cost Breakdown for a Typical Paper Machine Producing Linerboard United States (US$ per tonne of paper)

	Recycled Fibre	Virgin Fibre
Raw Materials	247	142
Energy	20	43
Other Production Costs	76	98
Capital Charges	77	99
Delivery Costs to Domestic Market	52	55
Total Costs	472	439

Source: IIED Sub-Study No. 11

Huston (1995) provides another comparison of the costs of producing newsprint using recycled fibre and virgin fibre (TMP). He finds that capital costs are very similar and that key factors in the comparison of operating costs are the price of the raw materials and energy. For TMP, energy costs can account for 20-45% of the variable cost of production while raw material ranges between 30 and 60%. For de-inked pulp, energy costs are generally lower and range between 10 and 20% of variable manufacturing cost. Raw material in this case accounts for 40-60% of the variable cost. For other types of production costs, Huston found that there was not a particularly significant difference in terms of labour costs between recycled fibre and virgin fibre mills, or in overhead costs. A difference was however seen in terms of chemical costs, to the disadvantage of recycled fibre mills (see Table 5b). Overall, he finds that there is a slight variable cost advantage in using deinked pulp although this would not hold in situations where wastepaper prices are high and energy prices are low.

Table 5b Comparison of Production Costs Using Virgin and Recycled Fibres for the Production of Newsprint

	Virgin Fibre - TMP	Deinked Pulp
Labour		
Pulp Process	9.00	10.25
Maintenance	2.25	1.75
Chemicals	10.00	25.00
Supplies		
Pulp process	3.00	3.00
maintenance	5.50	2.50
Miscellaneous operating	15.00	10.00
Overhead	5.00	5.00
Solid-waste disposal	0.00	8.75
Total (excluding raw material and energy)	49.75	66.25

Source: Huston (1995)

In the UK, a social cost benefit analysis of newsprint recycling estimated the cost of producing newsprint from virgin fibre at £342 per tonne in 1994 compared with £266 tonne for newsprint based on wastepaper in 1994. Thus the cost of virgin-fibre based newsprint was found to be 29% higher than that of newsprint produced from recycled fibre. This included all the costs of collection and sorting of waste paper (BNMA 1995).

A recent study in the United States (Ince 1995) also demonstrates the cost advantages of using waste paper in newsprint manufacture. At late 1994 prices, total production costs were estimated at approximately US$490 per tonne for virgin fibre newsprint, compared to US$430 per tonne for newsprint based on recycled fibre (these are estimates rather than actual mill data). It also shows how energy prices can affect the comparative cost advantage of recycled newsprint. As recycled newsprint typically has a lower electrical energy input, an increase in the price of electricity will enhance its cost advantage.

Other financial benefits to producers of using recycled fibre are commonly quoted. Firstly, there is greater flexibility in increasing output. Recycling plants can operate on a viable basis at a lower scale than virgin pulp plants, thus allowing smaller increments of output,

while the amount of waste paper used can be adjusted according to availability (Higham 1995, EDF 1995). For fibre deficit countries, recycling has the advantage of reducing foreign exchange requirements and vulnerability to exchange rate changes.

Developing countries can benefit from the use of waste paper as it permits the use of smaller mills with capacity more appropriate for the size of the local markets. A number of countries rely heavily on imports of waste paper to meet their fibre needs and have built up their paper industry on this basis. Taiwan, for example, had a waste paper utilisation rate of 98% in 1993, with imports accounting for 40% of waste paper inputs (PPI 1995). Imported waste paper is generally of higher quality than local supplies and therefore complements rather than displaces local recovery systems. This has been demonstrated by a recent study of the waste paper sector in India which finds that given the characteristics of the existing pulp and paper technology, there is very limited scope for substitution between domestic waste paper and imported waste paper (Ramaswamy *et al.* 1996, Beukering and Duraiappah 1996). Recently, with the increasing waste paper utilisation in Europe and North America, there have been concerns about the continued availability of low cost imports. Some countries, for example, Thailand and Indonesia, are now aiming to increase domestic waste paper recovery in order to reduce dependence on imports (IIED Workshop 1, 1995).

Comparisons of Collection and Sorting Costs with Waste Disposal Costs

Much of the effort to increase recycling has been directed at MSW and in particular, to household waste. Collection of waste paper and other recyclables from industrial or commercial sources is generally considered cost-effective and less in need of active promotion. In many cases, waste paper is collected from households as part of a programme aimed at various types of recyclable material. Recycling costs are therefore considered in terms of the overall scheme rather than for paper specifically. Some argue that this is the only way that collection of recyclables from households can be feasible in the long term. But separate schemes for paper have recently been introduced in some areas, for example in some parts of the UK to supply local mills or the export market (Waste Manager March 1996).

The costs of collecting recyclables from residential areas vary considerably by location and type of scheme, as do sales revenue and avoided waste-management costs - against which they should be compared. There is also some evidence that collection and sorting costs can decrease over time as greater experience is gained and participation improves. This makes comparisons difficult.

Household waste can be amassed using a variety of schemes, e.g. "Bring Scheme", "Kerbside Collection Scheme", "Single Material Collection Scheme", "Mixed Material Collection Scheme". These alternative means are typically of significant importance in determining the costs of recycling.

Box 5a Types of Recycling Schemes

Bring Recycling Scheme - Householders required to take recoverables to one of a number of collection points, situated away from their residence.

Kerbside Recycling Scheme - Householders place recoverables in container/bag on a specific day, in the immediate vicinity of property for collection.

Single Material Collection Scheme - Kerbside recycling scheme in which there is a separate collection for each of the materials to be collected.

Multi Material Collection Scheme - Kerbside recycling scheme in which more than one specified material is collected.

Source: ERRA 1994

Two indicators are commonly used to assess the effectiveness of recycling schemes:

- Participation rates - the percentage of households in a given area who participate in recycling

- Capture rate - the percentage of recyclable materials collected from households participating in a recycling scheme. This measures the extent to which households separate recyclable waste from the rest of their waste.

A survey of recycling schemes in the US found that participation rates for kerbside schemes ranged from 60% to 95% across all types of scheme and from 70 to 88% for schemes where materials are sorted by the household. For areas with drop-off or bring schemes, participation was found to be considerably lower, ranging from 4% to 28%. Capture rates were typically between 85% and 95% for newspapers and magazines (Franklin Associates 1994).

Evidence from Europe also indicates the greater effectiveness of kerbside compared with bring recycling schemes. Table 5c shows potential and actual diversion rates in various European regions. The potential diversion rate is the percentage of the total wastestream that is recyclable and hence could be diverted for recycling. It can be seen that the actual diversion rate is somewhat higher for the two kerbside schemes.

Table 5c Potential and Actual Diversion Rates

Type of Scheme	City	Potential Diversion Rate	Actual Diversion Rate	Difference (%age points)
Bring	Barcelona	38%	8%	30
Bring	Prato	25%	9%	16
Kerbside	Dublin	30%	17%	13
Kerbside	Lemsterland	36%	30%	6

Source: ERRA 1994

The importance of convenience in explaining this difference is illustrated in research conducted in Austria which looked at how the levels of participation in secondary material collection schemes varied according to how far away the collection container was placed.

Table 5d The Impact of Convenience on Participation

Utilisation of secondary material containers	Container Site				Irregularly/ unknown
	In House	Walking Distance (minutes)			
		up to 5	5 to 15	over 15	
regularly	88	70	55	27	78
occasionally	8	22	30	39	16
never	3	7	13	33	3
unknown	1	1	2	1	3
Total	100	100	100	100	100

Source: International Solid Waste Association (ISWA 1995)

Table 5d shows that containers placed at the maximum convenience to residents were used most often. Nearly 90% of residents who had recycling containers placed within their house used the containers regularly. Of the residents who had to walk over 15 minutes to get to the nearest recycling container, only 27% of them used the container regularly while 33% never used them. The conclusion to be drawn is that kerbside schemes are likely to be necessary if a significant increase in paper collection is required.

Estimates of Collection Costs

Most analyses of recycling carried out before 1995 concluded that solid waste management systems involving recycling particularly where kerbside collection is required can prove more expensive than systems based primarily on landfill and incineration.

United States

1) Franklin Associates/Keep America Beautiful Inc 1994
Kerbside recycling on average adds US$13-17 per ton of waste or US$0.95 - 2.15 per household per month to the overall costs of residential waste management depending on the extent of recovery. This comparison is with a waste system based entirely on landfill. Kerbside recovery increases total system costs by 15-19%. The main reason for this is that avoided collection and disposal costs for recycled MSW are seldom proportional to the reduction in quantities going to landfill. When a recycling programme is introduced unit costs of collection and disposal of remaining MSW often increase. Costs of drop-off schemes are not estimated because of their wide variation. Estimates from the literature ranging from US$27 per ton to US$200 per ton are quoted.

2) Solid Waste Association of North America 1995
There is considerable variation but the rule of thumb is that net costs of recycling (collection and sorting net of sales for recyclables in general) are in the range of US$100-160 per tonne. This breaks down as:

- Collection of solid waste and recyclables: US$60-100 per ton

- Processing of recyclables: US$40-60 per ton

Case studies of some cities: Minneapolis, Scottsdale, Sevierville, Springfield and Palm Beach show that waste diversion, recycling and resource recovery programmes tend to increase the cost of MSW management, whereas in Seattle a significant cost saving was observed.

3) Chaz Miller, National Solid Wastes Management Association 1993

Gross costs per ton for co-mingled kerbside recycling are in the range US$102.9 for a small truck and 75% set-out rate to US$148.77 for a large truck and 25% set-out rate (household participation rate). Revenue from sales is not estimated but a recent estimate of less than US$40 per ton of commingled recyclables is quoted.

Europe

1) European Recovery and Recycling Association (ERRA) 1994

Four recently introduced schemes were analysed: 2 kerbside schemes (Adur (UK) and Dunkirk) and two bring or drop-off schemes (Barcelona and Prato). The costs of the waste management system were found to have risen by 7 and 10% for the two bring schemes and by 16% in Dunkirk and 35% in Adur. This implied an additional £17 or US$25 per tonne of waste in the Adur scheme.

Table 5e Diversion Rate and Potential Cost Increase in Four European Schemes

	Adur	Barcelona	Dunkirk	Prato
Diversion rate	20%	8%	17%	9%
% increase in total waste management cost	35%	7%	16%	10%

Source: ERRA, 1994

It should be noted that Adur is a blue box multi-material scheme in which collection of recyclables takes place separately from collection of waste. Recyclables are sorted during the collection process. Dunkirk is also multi-material but sorting takes place after collection. This may explain why the cost increase is lower in this case than for Adur.

For the following year costs in the Adur scheme were projected to decrease such that overall system costs would be only 15-20% higher than with a disposal only scheme. This would equate to an additional £7-9 or US$10-13 per tonne. This was because of increases in capacity utilisation and in the number of properties served per vehicle per day. In addition, in a new scheme in Worthing, building on lessons learned in neighbouring Adur, the additional collection costs have been reduced to £1.33 per household per year with the expectation that by the end of 1996 they will be less than £0.30 per household per year. This represents a cost increase of less than 1% (IGD 1996).

2) UK Department of Environment 1993 - Coopers and Lybrand

The study considered schemes which were integrated with the normal system of refuse collection and produced a range of net costs at £55-£175 per tonne. These take into account any reductions in cost of the normal refuse collection scheme and therefore should be compared with disposal costs alone. Avoided disposal costs were estimated to range from

£5 to £30 per tonne. By 2000, landfill costs were expected to rise to £10-45 per tonne (in 1992 prices) reflecting the effects of stricter environmental requirements.

3) Department of Environment 1992 - Environmental Resources Limited
The study estimates the incremental net collection costs (collection net of sales of recyclables) at £173-266 per tonne compared with avoided landfill and collection costs of £30-52 per tonne. The high collection cost reflects the fact that the recyclable scheme would be separate from and additional to the normal mixed refuse collection scheme. Because of the high fixed cost of waste collection and the difficulty of reducing collection frequency, the avoided costs of collection resulting from introduction of the blue box scheme were assumed to be quite low at £9 per tonne in relation to the average refuse collection cost of £35 per tonne. Total avoided costs of disposal and collection were therefore estimated at £30-52 per tonne, considerably less than the costs of kerbside collection.

Most of these studies indicate that kerbside recycling and in some case drop-off recycling can increase the costs of waste management. The situation may be changing, however, as the prices of recyclables have increased and collection costs have been reduced through efficiency improvements. In Europe, net costs are falling in a number of schemes due to several factors, such as increases in sales revenue, modification of collection systems and economies of scale achieved through programme expansion (Hummel, White and Willmore 1996). In the United States, some recycling programmes are generating sales revenues that are comparable to collection and sorting costs reflecting current high prices of recyclables (Scarlett 1995). The EDF Paper Task Force notes that in 1995 a number of cities implemented kerbside recycling programmes with little or no increased costs over their existing refuse collection and disposal systems, and that Seattle was likely to incur significant savings as a result of its recycling programme (EDF 1995).

Much depends on whether the current high prices of recyclables can be expected to continue. The view of Franklin Associates in a comprehensive study of recycling in the United States is that prices can be expected to fall again and that a long term perspective is needed (Franklin Associates 1994). Some support of this view is given by a recent survey of recycling schemes in the United States. Of the 46 state recycling managers reached, 22 indicated that the sharp drop in waste paper prices at the end of 1995 had adversely affected their recycling programmes (Raymond Communications 1996).

Waste Disposal Costs

The cost of waste disposal is also an important factor as it has been increasing in most countries as a result of stricter environmental standards. Thus financial comparisons between paper recycling and waste disposal are subject to some uncertainty. While the balance was clearly unfavourable to recycling in the early 1990s the current situation is less clear.

A study conducted by Repa (1993) of the National Solid Waste Management Association showed that the national average landfill tipping fee in 1992 was US$31.60 per tonne (US$31.20 per ton) compared with US$8.71 per tonne (US$8.57 per ton) only seven years earlier. The marked rise in cost over the examined time period reflects shortages of landfilling space in some parts of the United States as numerous landfill sites have been

closed down, following tighter environmental standards. The largest increase in cost occurred in the North Eastern part of the United States, while the lowest rise was in the South Central region.

Table 5f Landfill Tipping Fees in the United States (US$/ton)

	1985	1986	1987	1988	1990	1992
Northeast	12.66	17.11	52.41	16.11	64.76	65.83
Mid-Atlantic	16.99	22.08	26.32	33.84	40.75	47.94
South	3.24	5.76	13.13	16.46	16.92	22.48
Mid-West	7.23	11.75	16.42	17.70	23.15	27.10
West Central	5.36	6.21	7.23	8.50	11.06	12.62
South Central	7.24	7.61	10.17	11.28	12.50	12.53
West	10.96	11.10	13.92	19.45	25.63	27.92
National	8.57	11.81	19.40	22.74	26.56	31.20

Source: Repa 1993

The figures shown in the above table mask differences between cities and states but are broadly consistent with the results of another survey (Biocycle Nationwide Survey - Steuteville 1995) which showed average landfill tipping fees in each state. The lowest average tipping fees were found in Arkansas at around US$20 per tonne and the highest in Connecticut at US$60 per tonne.

In Europe, the problem of shortage in landfill space is only just beginning to emerge. Landfill costs in some parts of the continent are still quite low though they are expected to rise. Results from a study conducted by Juniper Consultancy Services Limited found average landfill costs in a number of European cities to range from US$12 per tonne to US$80 per tonne. This is illustrated in the Table 5g below:

Table 5g Average Landfill Costs in Europe

Country	Average Landfill Costs - US$ per tonne
Belgium	40
Denmark	45
France	35
Germany	70
Italy	50
Netherlands	50
Norway	80
Sweden	40
Switzerland	40
United Kingdom	20
Spain	12

Source: Juniper Industry Survey 1995

White, Franke and Hindle (1995) also survey landfill costs in Europe and find that there is considerable variation. Costs are lowest in Italy at US$1.25 per tonne and highest in Austria at US$220. They point out that these do not include costs of remediation following

leakages and accidents and that the real costs of landfilling are likely to be higher. This issue is discussed further in Section 6.

Incineration

In both Europe and the United States, available figures indicate that incineration is usually more costly than landfill.

According to the Biocycle Nationwide Survey mentioned above, average incineration tipping fees in the United States in 1994 were around US$49 per tonne (£33 per tonne). However there was considerable variation around this average. Lowest average tipping fees were found in Arkansas at US$20 per tonne (£14 per tonne), and the highest in Alaska at US$81 per tonne (£54 per tonne). Table 5h gives the estimates for a number of states in the US.

Table 5h Incineration Costs in the United States 1994

State	Incineration - Average Tipping Fees (US$ tonne)
Alaska	80.00
Arkansas	20.00
California	27.50
Connecticut	73.00
Florida	60.00
Massachusetts	50.00
Minnesota	63.50
New Hampshire	45.00
Virginia	35.00

Source: Steuteville 1995

Research undertaken by the Energy Technology Support Unit (ETSU) of the UK the Department of Trade and Industry shows estimated tipping fees in some parts of Europe to be similar to the US average fees found in the Biocycle Nationwide Survey. ETSU examined the costs of three generic types of mass burn waste to energy systems, for waste inputs of 200,000 (Scheme A) and 400,000 (Scheme B) t/y of municipal solid waste. The study estimated that gate fees in the UK for the two levels of waste inputs would be £39.09 per tonne and £26.53 per tonne respectively, not taking into account any subsidies available (DTI 1993).

ETSU also surveyed costs of waste-to-energy facilities in France, The Netherlands, and Germany (Scutter and Dyke 1994). Wide variations in capital costs were found. In Germany and The Netherlands, plants have equipment designed to meet the latest emissions standards with the result that capital costs there are up to three times as much as those for French plants and estimates for future plants for the UK. Gate fees in Germany and The Netherlands were found to be as high as £80 per tonne while in France gate fees were £30-37 per tonne on average.

The wide variation in incineration costs around Europe is reiterated in research undertaken by Juniper Consultancy Services Ltd.

Table 5i Average Incineration Costs in Europe

Country	Average Incineration Costs - US$ per tonne
Belgium	50
Denmark	35
France	60
Germany	165
Italy	55
Netherlands	75
Norway	80
Sweden	40
Switzerland	130
United Kingdom	30
Spain	30

Source: Juniper Industry Survey 1995

Another survey of costs of incineration in Europe is given by White, Franke and Hindle (1995). They conclude that costs depend principally on the following factors:

- incinerator capacity
- level of gas cleaning equipment installed
- whether energy is recovered or not
- whether economic instruments exist to encourage the generation of power from waste.

They find a very wide variation in costs per tonne of waste from US$26 in Denmark to US$450 in Germany.

Estimates of landfill and incineration costs from the different sources the different sources discussed above are summarised in Table 5j. It can be seen that there is considerable variation but that landfill is generally cheaper than incineration.

Table 5j Costs of Landfill and Incineration for MSW in Europe and the United States

Country/Region	Landfill Costs US$/tonne	Incineration Costs US$/tonne	Source
Europe	1.25 - 220 59 (average)	26 - 450	White, Franke and Hindle 1995
	12 - 80	30 -165	Juniper 1995
United States	n/a	70 - 120	White, Franke and Hindle 1995
	8 -74 29 (average)	20 - 89 47 (average)	Steuteville 1995 (Tipping fees)
	20.5 - 59.4	71	Franklin Associates 1994

Key factors which affect the cost of incineration are throughput and the calorific value of the waste. A common concern is that recycling, because of its potential effect on the volume and characteristics of the residual waste stream, is in conflict with incineration. This is particularly relevant to paper because of its high calorific value. Estimation of the calorific value of waste

under different recycling scenarios has been made in Germany (Habig in White, Franke and Hindle 1995) and the UK (Warren Spring Laboratory in Porteous 1996). In both cases the conclusion drawn is that recycling has little effect on the calorific value of the remaining waste even where the diversion rate of recyclable paper and other materials approaches 50%. The positive effect on calorific value of removing putrescibles may be much more important. Effect on throughput may be more serious and anecdotal evidence exists of this although it is difficult to separate out the effect of competition from landfill.

The approach taken to waste management is of key importance here. If an integrated approach is adopted which recognises the role of different waste management options, then incinerator capacity can be matched to waste volumes after materials recovery has been allowed for (White, Franke and Hindle 1995). This still leaves open the question of how much materials recovery is appropriate. The available evidence suggests that as collection technology and management improves and as waste disposal becomes more costly, the recovery of some types of waste paper, for example, newspapers, will become more viable in the future. For other types of waste paper, such as low grade household packaging or newspapers from rural areas, viability will remain questionable.

6. MONETARY VALUATION OF THE ENVIRONMENTAL IMPACTS OF WASTE DISPOSAL

Estimation of the monetary value of the environmental impact of waste disposal, for example of incinerator emissions or methane and leachate generation in landfills, would ensure that decisions on recycling or waste disposal were based on the full social cost of the different alternatives. A few attempts at such valuation have been made in the United States and in the UK. Results have tended to vary considerably and are either very site-specific or subject to a high degree of uncertainty. In some cases estimates have proved to be very low.

In the UK, the landfill tax which has just been introduced is based on estimates of the external costs of landfill and incineration (Department of Environment 1993a). The study distinguished between *fixed externalities* relating to the disamenity of the site, e.g. visual, noise and odour impacts which occur by virtue of the existence of the site and *variable externalities* which relate to the emissions, effluent and solid waste releases from the sites and which depend on the quantity of waste disposed of. The variable externalities consist of the following:

- Global warming risk through the release of CO_2 and CH_4
- Damage caused by air pollutants: SO_2, NO_x and particulates
- Damage caused by airborne toxic substances from incinerators i.e., heavy metal, dioxins and other organic compounds
- Damage from leachate from landfills
- Pollution and accidents associated with the transportation of the waste to landfill and incinerator sites.

The study authors did not evaluate the externalities related to the disamenity of the site. To estimate disamenity values it was claimed that a further study involving hedonic pricing or contingent valuation would be required. They did however review a number of studies of landfill disamenity costs in the US based on both hedonic pricing and contingent valuation from which they derived a tentative average disamenity value of £160 per household, representing the willingness to pay to avoid being located near a landfill site. They were reluctant however to apply this value to the UK context because they doubted whether valuations relevant to the US sites were applicable to UK sites.

The variable externalities were evaluated on the basis of previous studies estimating the damage costs of global warming, air pollution and loss of life and limb. These values were applied to emission or impact coefficients calculated per tonne of waste. The value of these coefficients depended on the waste disposal scenario chosen. The scenarios were developed to cover the following:

- Urban and rural sites for landfill
- Landfill with and without energy recovery
- Urban and regional incinerators both with energy recovery.

With the unavailability of any previous economic valuations, leachate damage costs were estimated on the basis of accident clean up costs and accident frequency at different sites. The authors noted that this method is not entirely satisfactory as a measure of willingness to pay to avoid such damage but pointed out that the latest technology for landfills, which involves containment means that such damages are minimal.

Though air toxics were identified as a source of external damage, they were not assessed for two reasons:

- The lack of risk analysis to enable the emissions from incinerators to be related statistically to risk to human health or the incidence of mortality and morbidity.

- The conclusion of the Royal Commission on Environmental Pollution that the emissions from a well operated incinerator plant complying with the new standards applicable in England and Wales are unlikely to have any health effects.

It was also acknowledged that road congestion costs associated with transport of wastes to the sites were not included.

The external benefits of displacement of pollution as a result of energy recovery in landfill and incineration schemes were also evaluated.

Landfills in the UK were estimated to have net external costs of £1-4 per tonne of waste, while incinerators operating to new plant emission standards and with energy recovery were considered to provide an environmental benefit of £2-4 per tonne of waste, because of the displacement of energy generation from coal. The actual landfill tax implemented has been set at £7 per tonne for normal MSW and £2 per tonne for inert waste. It remains to be seen what impact this tax will have on recycling levels.

The study excluded some pollutants, such as chlorinated organics, on the grounds that these would be sufficiently controlled under proposed UK environmental legislation. But emission limits for these pollutants are somewhat stricter in other countries such as Germany and the Netherlands, where considerable expenditure has been made to bring some incinerators into compliance (Scutter and Dyke 1994). Incineration fees are consequently much higher than in the UK.

Repetto *et al.* (1992) cite other studies in the United States which give significantly higher estimates of US$75/ton and US$67/ton but provide little details of the method and scope of these valuations.

A further constraint on the UK valuation was that it concentrated on so-called variable externalities, which relate to the emissions, effluent and solid waste releases from disposal sites and depend on the quantity of waste. The NIMBY factor is driven much more by fixed externalities, relating to the disamenity of the site, and these were not covered in the valuation. This echoes some of the problems associated with the LCA studies, namely, the inability to address less tangible impacts in the assessment.

Estimation of Fixed Externalities

Research in the United States has attempted to estimate this type of external cost but again the results appear low in relation to waste disposal costs.

Contingent Valuation Approaches

One study in Knox County, Tennessee, has estimated average willingness to pay to avoid siting of a landfill in their community at US$227 per household per year, or US$160,000 per year for the whole population affected (Roberts *et al.* 1991. In a survey respondents were asked to indicate the maximum amount of money they would be willing to pay to avoid a landfill. The results are set out in Table 6a.

Table 6a Frequency Distribution of Household Willingness to Pay to Avoid a Landfill in the Carter Community, 1988

Range of annual household willingness to pay	Number reporting	Percent
0	19	13.6
1-25	5	3.6
26-50	13	9.0
51-75	34	24.3
76-100	14	10.0
101-200	19	13.6
201-500	24	17.1
501-1000	5	3.6
1001-1500	4	2.9
1500-2000	3	2.1
	140	100.0

Source: Roberts *et al.*(1991)

It can be seen 19 respondents were unwilling to pay anything to avoid a landfill. Of this group 12 indicated that they could not afford to pay and 7 said that they did not believe that there was a danger from landfills.

The researchers also investigated the relationship between household characteristics and willingness to pay. Only age and home ownership were found to be completely insignificant in explaining the level of willingness to pay of respondents. Income and education were both found to be positively correlated with willingness to pay. Females were found to be willing to pay US$157 less than male respondents while respondents who depended on piped city water or bottled water for drinking were willing to pay US$141 less than those who relied on well or spring water. Those who said they were concerned about health risks from the proposed landfill were willing to pay £332 more than those who said they were unconcerned. Finally, the number of years in residence was positively related to willingness to pay.

Hedonic Price Approach

The hedonic price approach uses changes in property values as a proxy for the effect of externalities. An example of a study based on this approach is that conducted by Nelson et al (1992) in Ramsey, Minnesota. The effects of a landfill on the prices of 708 houses in a community during the 1980s were examined. The results showed that property values rise about 6% per mile from the landfill boundary out to a distance of 2 miles, beyond which there is negligible impact on prices. At the landfill boundary, house prices can drop by as much as 12%. Prior to this study, Havlicek (1985) undertook research which found that a house located one mile closer to a landfill than a similar house would be valued about US$3,640 less. House prices rose about 5% per mile away from the landfill.

A study of housing prices in the vicinity of an incinerator also confirmed that the facility affected the local housing market (Kiel and McClain 1995). The Kiel and McClain study is different to previous studies in that it focuses on the effect of the siting of an incinerator on property *appreciation* rates rather than "one off" property values. Differences in appreciation rates capture the speed of adjustment to new price levels and are evidence of a disequilibrium in the housing market due to the presence of the facility. If prices adjust quickly and completely then the change in price can be measured at any two points before and after the siting, as the effect of the impact will not change over time. If the price level adjustment takes time, then the appreciation rate is negatively influenced and the impact on the home-owner cannot be quickly measured.

Kiel and McClain studied the impact of the siting of an incinerator in North Andover, Massachusetts on housing appreciation rates in the surrounding area. An income capitalization model and a repeat sales technique were used to examine the relationship between appreciation and the location of the house relative to the incinerator. Changes in the probability of an incinerator siting and in the likelihood of damage were also considered.

Results from both techniques showed that appreciation rates fall during both construction and operation of a facility. They are also affected by the distance of property from the facility. Even seven years after the facility started operating the researchers observed differences in appreciation rates between property sited close to the incinerator and those sited further away.

The implication is that estimation of the external costs of waste management by means of property prices requires examination of changes in price levels at various stages including well after the facility has gone into operation.

Implications of the Fixed Externality Estimates

Neither of the two landfill studies discussed in detail above relate the values obtained to tonnages of waste and disposal costs. On the basis of some assumptions about landfill capacity and operation and housing rental value, however, we have made some very rough calculations (set out in Box 6a) to examine the implications of the externality estimates. In both cases, our calculations suggest that payment of compensation to affected households in line with the externality estimates would have very little effect on average waste disposal costs.

Thus available estimates of both fixed and variable externalities or the amenity costs of waste disposal facilities prove to be rather low, raising questions about existing or proposed policy measures to reduce waste by promoting further recycling.

Box 6a Back of the Envelope Estimate of the Implications of the Fixed Externality Estimates

Study 1: Estimating External Costs of Municipal Landfill Siting Through Contingent Valuation Analysis: A Case Study (Roberts *et al*, 1991)

Average willingness to pay (WTP) per household to avoid siting of a landfill in their community (Knox County, is estimated at US$227 per year). There are roughly 708 families in the community so total annual WTP equals US$160,000. Landfill capacity is not stated but a capacity of 200,000 tons per year is sufficient to deal with the waste of a medium-sized city. Even assuming a landfill a quarter this size, the fixed externality estimate equates to US$3.2 per ton of waste per year.

Study 2: Price Effects of Landfills on House Values (Nelson *et al*, 1992)

The study (in Ramsey Minnesota) estimates that house values rise about 6% per mile from the landfill boundary to about 2 miles beyond which there is negligible impact on prices.

Assuming that pre-landfill house values were US$100,000 per house and that properties are equally distributed within the 2 mile radius of the landfill, there is an average reduction in price of US$6,000 per house. About 700 properties were affected implying a total potential drop in sales value of US$4.2mn. Converting this figure to an annual loss in rental value, assuming 5% and 8% interest rates and 20 years and 50 years time horizon, gives a range of rental value changes from US$230,062 to US$427,779. The capacity of the landfill is 500 tons per day. This is assumed to operate either 250 days per year or 365 days per year giving a total annual capacity ranging from 125,000 to 182,500 tons per year. Dividing the change in rental value by the annual capacity gives estimates ranging from US$1.26 per ton (5%, 50 years, 365 days per year) to US$3.42 (8%, 20 years, 250 days per year).

7. CONCLUSIONS

Decisions about the extent of paper recycling that is appropriate need to be based on an assessment of environmental, social and economic factors. In this sub-study we have examined the evidence available from life cycle environmental comparisons of recycling, landfill and incineration and waste paper. We have considered the social issues associated with these options and compared their costs. We conclude that the environmental advantages of paper recycling over incineration have not been clearly demonstrated. There may be situations therefore where recycling is not the best solution if economic factors are taken into consideration. For certain types of waste paper, other options such as incineration may be less costly. A complicating factor is that recycling has proved to be extremely popular while incineration facilities have tended to encounter community resistance. The reasons for this are not clearly understood and require more attention.

Environmental Issues

Incineration with energy recovery, provided it has modern emission control technology, can be an acceptable disposal option for waste paper and waste in general. In terms of emissions it compares well with other means of energy generation. Life cycle comparisons of wastepaper recycling and incineration have not found significant advantages in paper recycling. If anything, incineration appears more favourable. Such comparisons depend heavily on assumptions made about technology, and a key problem is that numerous incinerators with inadequate emission control technology are still in operation.

Landfilling of paper has environmental disadvantages in relation to recycling and incineration. On environmental grounds the share of waste paper going to landfill should therefore be reduced. However, it is often significantly less expensive than other options. Taxes on landfill to internalise environmental costs may be an effective way of achieving the appropriate mix of waste management options. Where the alternative to recycling is landfill or old-style incineration, then recycling is the environmentally preferred option.

Social Issues

Recycling has been associated with social benefits such as employment but the evidence for this is patchy. It is particularly important as a source of income and employment in the informal sector in developing countries although it is also associated with a number of social problems such as poor living conditions and lack of security and status. It enjoys a significant amount of support from the public as evidenced by high levels of participation where schemes exist and survey of public attitudes. At the same time there is significant community resistance to the siting of new landfill or incineration facilities. The reasons for the NIMBY factor are not clearly understood and it cannot be dismissed as irrational. There are genuine concerns about waste disposal that need to be recognised. Attention has to be directed towards understanding the factors driving the NIMBY factor and to increasing public acceptance of waste-to-energy facilities as an alternative to recycling where it has economic advantages.

Economic Issues

Recycling of waste paper, particularly that collected from households, has in the past suffered from problems of financial viability owing to high costs of collection and sorting and variable revenues. The situation may be changing, as improvements in collection technology and organisation have brought down costs. The increase in waste paper prices during 1994 and 1995 also appears to have affected the viability of recycling. As prices have subsequently fallen again it remains to be seen whether the financial viability of recycling can be sustained. If prices continue to fall significantly, then some degree of subsidy will be required. This subsidy can only be justified by reference to the avoided external costs of waste management (such as emissions from incineration or leachate generation from landfills) which are not reflected in charges for waste collection and waste disposal. However, subsidising recycling provides no incentives for waste reduction at source.

Relatively little work has been done on monetary valuation of the external costs of waste management. The few estimates that exist tend to vary considerably, are site-specific and subject to considerable uncertainty. As yet, they provide little support for subsidising recycling.

Recycling is likely to be financially viable where waste paper is generated in large quantities and/or is clean. For mixed dirty waste paper, other options seem more appropriate. These could include incineration, provided that stringent emission limits are achieved, or composting. An integrated approach is required which recognises the potential contribution of different options for waste paper and plans for them effectively.

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