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Technical Report on Waste Management

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Municipal solid waste management

This Report has been prepared by RIVM, EFTEC, NTUA and IIASA in association with TME and TNO under contract with the Environment Directorate-General of the European Commission. This report is one of a series supporting the main report: *European Environmental Priorities: an Integrated Economic and Environmental Assessment*.
Reports in this series have been subject to limited peer review.

The report consists of three parts:

Section 1:
Environmental assessment
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Section 2:
Benefit assessment
Prepared by D.W. Pearce, A. Howarth (EFTEC)

Section 3:
Policy assessment
Prepared by D.W. Pearce, A. Howarth (EFTEC)

References
All references made in the sections on benefit and policy assessment have been brought together in the *Technical Report on Methodology: Cost Benefit Analysis and Policy Responses*. The references made in the section on environmental assessment follows at the end of section 1.

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1. Environmental assessment

1.1 Introduction

The 5EAP recognised the ever increasing waste generation as one of the prominent environmental problems. It required the Member States to reverse this trend as waste dumping sites form a nuisance for ground water quality as well as a visual intrusion of the landscape. The general policy was to move away from landfilling towards composting and recycling. Waste that could not be reused should be incinerated generating electricity to displace conventional coal firing under the slogan ‘waste to energy’ (WTE).

Despite the incentive of the 5th EAP, EU annual municipal solid waste (MSW) arising rose from 330 kg per capita to about 420 kg per capita in the time period 1980 to 1990. In absence of any effective waste prevention policies, projections of waste arisings reach 440 kg per capita by 2000 [Coopers and Lybrand, March 1996]. Recent reports already give around 503 kg per capita in 1993 [EEA, June 1998], which reflects the accelerated rate of economic growth since the recession in the early nineties. Driven by an economic growth of some 40% the BaseLine scenario (BL) estimates the municipal waste arising at 590 kg per capita by the year 2010 [EEA, June 1999]. To oppose this trend the Accelerated Policy scenario (AP) aims at both waste prevention and increasing the waste fractions to be either composted or recycled. Landfilling is discouraged, incineration has been regulated by stricter safety rules to stop air pollution. According to this scenario, 3% of the BL arisings can be prevented in 2010, while Composting and Recycling may take 58% of the remaining total waste arising.

It needs to be noted that the cost curves used for this study are derived from Coopers and Lybrand 1996 which was based on 1993 data. The figures used for recycling, in particular of plastics, refer to cost-optimized situations based on these data which may differ significantly from empirically measured data, in particular for plastics. This, however, does not change the validity of the conclusion that high levels of recycling of glass, metals and paper are optimal from a societal point of view.
At the same time for individual member states the baseline projection concerning composting for 2010 already underestimates the state of the art for the year 2000 due to the methodology applied which extrapolates from the Cooper & Lybrand data. However this will not change the main conclusion that there is a huge potential for composting in the EU.

This technical report consists of three sections:
1. This short introduction.
2. Environmental trends: providing a problem sketch, evaluating the BaseLine scenario, explaining the methodology used, and presenting the scenario results.
3. The section on Conclusions capsulizes the conclusions drawn in the previous sections

There are four supporting Annexes that present technical background information of the methodology and data.

Annex I	Distribution of MSW-arising over treatment/disposal methods
Annex II	Distribution of MSW-treatment/disposal costs over different methods
Annex III	Distribution of the specific MSW-treatment/disposal costs over different methods
Annex IV	Assumptions for benefit calculations

1.2 Environmental trends and abatement costs

1.2.1 Problem sketch (DPSIR)

Though reliable data on waste arisings is scarce, historical trends for municipal waste show for practically all countries an increasing generation per capita [EEA, June 1998]. The underlying cause of the growth of MSW generation is the economic development involving increased production and consumption [EEA, 1995]. However, consumer attitude and activism surveys show that living standards in the EU Member States have reached the point at which awareness and willingness to reduce waste and recycle is apparent.

The pressures on the environment can be related to the arising of MSW: extra product manufacture (ending up as MSW) involves extraction of virgin materials and use of energy. On the other hand, each MSW management options has potential environmental impact on air (e.g. emissions of CH_4, CO_2, odours, SO_2, NO_x, dust, heavy metals) , water (leaching of heavy metals), soil (e.g. landfilling of slags, fly ash, final residues), landscape (e.g. soil occupancy, visual intrusion), ecosystems (e.g. contamination and accumulation of toxic substances in the food chain) and urban areas (e.g. noise, exposure of hazardous substances) [EEA, 1995].

The Waste Framework Directive requires Member States to take steps to prevent waste generation, to increase the capacity of incineration with energy recovery, to encourage recycling and composting , and to ensure safe landfilling . The general trend of increasing waste generation signals that waste prevention measures have not been sufficient. Also, landfilling remained the most common disposal method. The BaseLine scenario projects a slightly decreased share (from 57 to 52%) of the waste arisings to be landfilled, while Recycling and Composting increase from some 15% in 1993 to about 24% in 2010. This increase is related to additional Recycling of the waste fractions plastic and metals (besides paper and glass) due to the (interpretation of the) Packaging Directive.

Experts give a medium rank to Waste Management as a problem, whereas public opinion ranks it among the least issues of concern. Monetary evaluation suggests that large environmental benefits can be derived from reducing landfill disposal and promoting prevention and recycling [EFTEC, August 1998]. In table 1.A of Annex IV, these high net unit environmental benefits related to waste prevention and waste recycling are presented.

Current status of BL policies: policy gap or not

The following scenario's have been constructed based on assumptions on the implementation of the Packaging and Packaging Waste Directive (PPWD):

- Four out of six fractions of the MSW are involved in this Directive, namely: paper, glass, plastics and metal;
- Minimal 15% of each packaging fraction will be recycled in 2010;
- 25 to 45% recycling for the total (four) packaging fractions. Here it is assumed that 35% of the total packaging fractions will be recycled. In case, the overall recycling percentage of these fractions is higher than 35%, the overall recycling percentage is not lowered to 35%.

According to the PPWD, the Member States are required to reach these targets by 2001. For this study no further targets beyond that date have been set. The required 2001 situation is identical with the projected 2010 situation.

Incineration Directive

The EC Directives 89/369/EEC and 89/339 are focused on the prevention and reduction of air pollution from municipal waste incineration. They set standards for new and existing municipal waste incinerators. No direct influence on MSW arising nor MSW treatment/disposal methods. The Landfill Directive is not included in the BL-2010 scenario because it came into force after August 1997, the cut off date for BL policies in this project. It is therefore included in the AP scenario. None of the Directives is focused on reducing the MSW arising while the increase in MSW arising is one of the main causes resulting in the Waste Management problem.

Spillover

There is spillover with the environmental issue of Climate Change. Landfill of biodegradable waste (organic and paper waste fractions) without additional landfill gas recovery may result in uncontrollable emissions of methane from the landfill sites. Besides the incineration with energy recovery (Incineration WTE) may result in less combustion of fossil fuels and therefore causing a decrease in CO_2-emissions.

Some spillover with the environmental issues of Acidification and Eutrophication and Urban Stress. Incineration with/without energy recovery causes emissions of NO_x, SO_2 and PM_{10}. Closely related to the Incineration Directive.

Subsidiarity
MSW management is in the hands of municipalities. Legislation at the level of municipalities, Provinces or Nations may result in similar results. Optimum waste treatment/disposal strategies often depend on transport costs (population density), economies of scale and access to recycling industries.

Sustainability
It is generally accepted that current waste production trends and expected increases under current economic trends in European countries are unsustainable. To achieve sustainability entails both minimising the use of materials and reducing the impact of waste treatment/disposal [EEA, 1995].

1.2.2 Method

Indicators selected
We discerned 6 waste streams (organic, paper, glass, plastics, metal, and other) and 5 treatment/disposal methods (Landfill, Incineration, Incineration with energy recovery (Incineration WTE), Recycling, and Composting). The ashes resulting from Incineration with/without energy recovery form an indirect waste stream and are assumed to be landfilled (indirect Landfill). Besides, we distinct between rural and urban. Waste streams generated in a rural area are disposed of in the same way as urban MSW but with slightly higher costs. So this distinction is in fact a distinction in treatment or transport costs.

Outline of the datasets and models used
[EEA, June 1998] has supplied Municipal Solid Waste (MSW) projections (expressed in ktonnes/year) in the 14 EU-countries for the period 1990-2010. MSW-arising data for Luxembourg are lacking and have been constructed in the following way:

- GDP and total population data come from [NTUA, 1998];
- Specific MSW arising data per capita come from [Coopers and Lybrand, March 1996];
- Combination results in MSW arising projections for Luxembourg.

[Coopers and Lybrand, March 1996] has supplied the split-up percentages of the total MSW arising into the six fractions. Split-up percentages are available for the EU-12 countries. To complete the analysis for the three Member States lacking in (Coopers and Lybrand), the split-up of MSW-arising in Austria is assumed to be like the one in Germany while the split-up of the MSW-arising in Finland and Sweden, is coupled to the one in Denmark.

[World Resources, 1997] has supplied the split-up percentages of the total population into urban and rural populations for 14 EU-countries for the period 1995-2025. For Luxembourg, the total population split-up is lacking and has been constructed in the following way:

- The urban share in the total population of Luxembourg is assumed to be the average of the EU-14 as presented in [World Resources, 1997];
- The total population split-up in urban and rural fractions for 1993 and 2010 has been derived from the urban population percentages in 1995 and 2025 by extrapolation and interpolation respectively.

MSW-treatment/disposal targets.
There are four MSW-treatment/disposal scenarios starting from Base Line (BL-1993): Base Line (BL-2010), Technology Driven (TD-2010a, TD-2010b) and Accelerated Policies (AP-2010). Attention has been paid to five treatment/disposal methods, namely: Composting, Recycling, Incineration with energy recovery (Incineration WTE), Incineration and Landfill. Based on [Coopers and Lybrand, March 1996] a MSW-t distribution over these 5 methods is given for 1993 (BL-1993) for the EU-12 countries. Like the split-up percentages, the treatment/disposal method percentages of Austria agree with Germany while those for Finland and Sweden are like the ones in Denmark. The

distribution over the 5 treatment/disposal methods as described in [Coopers and Lybrand, March 1996] refers to direct disposal. After waste incineration (with/without energy recovery), incineration ashes remain that will be landfilled. In the original distribution of MSW over the 5 treatment/disposal methods these ashes are excluded while in the results here (disposed amounts and treatment/disposal costs) these incineration ashes are included.

Marginal cost functions related to the five MSW-treatment/disposal methods are derived from both [Coopers and Lybrand, March 1996] and TME cost data. Marginal costs are assumed to be the same for all EU-15 countries. So no distinction in for example the rural Composting costs in Denmark and Spain. This is largely dependent on the assumption that composting in e.g. Spain and Denmark are carried out on the same basis. However, much compost produced in Spain as well as in some other member states is actually from unsorted municipal solid waste, which would imply much lower marginal costs.
In total 32 marginal cost functions have been used:

1) Composting (2 functions):
   a) urban versus rural;
2) Recycling (24 functions):
   a) urban versus rural;
   b) paper, glass, plastics and metal;
   c) bring system, extra bring system (more containers) and kerbside;
3) Incineration (4 functions):
   a) urban versus rural;
   b) with versus without energy recovery;
4) Landfill (2 functions):
   a) urban versus rural.

In all marginal cost functions, the collection of MSW is included. In case of Composting and Recycling a separate waste collection took place.

Valuing Environmental Impacts from Waste Treatment/disposal Options (see Annex IV)
Net environmental costs associated with the different MSW treatment/disposal options for each Member State estimated for the base year 1993 are used across the different scenarios. These include all the impacts associated with emissions to air (e.g. NO_x, greenhouse gasses) and the risk of damage to health from the treatment of MSW, such as:

- Costs associated with the collection and transport of waste;
- Costs associated with energy use during the MSW management;
- Costs and benefits associated with the MSW process;
- Costs associated with the manufacture of bags / bins to collect MSW;
- Costs associated with road accidents during the transport of MSW.

Other factors taken into consideration include:

- Avoided costs of avoided virgin material production (due to recycling);
- Avoided costs of waste treatment/disposal due to prevention;
- Avoided costs of avoided virgin material production (due to prevention).

1.2.3 Identification of major uncertainties

It needs to be noted that the cost curves used for this study are derived from [Coopers and Lybrand, March 1996] which was based on 1993 data. The figures used for recycling, in particular of plastics, refer to cost-optimized situations based on these data which may differ significantly from empirically measured data. This, however, does not change the validity of the conclusion that high levels of recycling of glass, metals and paper are optimal from a societal point of view.
At the same time for individual member states the baseline projection concerning composting for 2010 already underestimates the state of the art for the year 2000 due to the methodology applied which extrapolates from the [Coopers and Lybrand, March 1996] data. However this will not change the main conclusion that there is a huge potential for composting in the EU.

It needs also to be noted that this assessment is necessarily incomplete since it only values emissions to air and the risk of damage to health. More work is needed to identify impacts to water and soil.

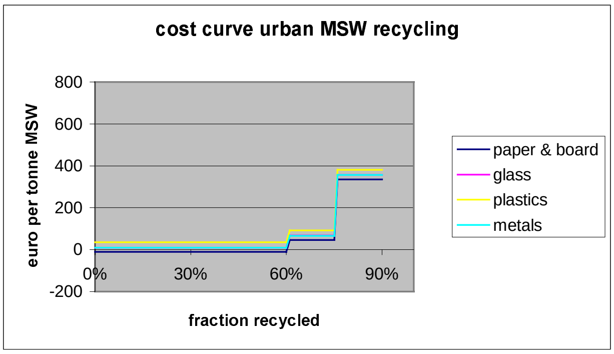
As will be described in more detail in the section Results, the distribution of the five MSW-treatment/disposal methods over the six fractions in the BL-2010, TD-2010 and AP-2010 scenario's has been based on interpretations of the Packaging and Packaging Waste and Landfill Directives. In AP-2010 also a MSW-arising prevention has been included. Here Norwegian prevention percentages have been used for all EU-15 countries. The Norwegian data come from [Bruvoll, 1998] and are limited to the fractions paper and plastics.

Marginal costs for the MSW-treatment/disposal methods are the same for all EU-15 countries. So no distinction in for example the rural Composting costs in Denmark and Spain. The split-up into the six fractions is in 2010 equal to the split-up in 1993. So it is assumed that the composition of the MSW will not change in the period 1993-2010.

Box 1 compares the recycling costs curves used in this study with a recent assessment of the financing needs for recycling in four Member States [SOFRES, 2000] commissioned by the EC.

Box 1 Cost curves for recycling of Municipal Solid Waste.

In many Member States the current MSW disposal method is landfilling. The Accelerated Policy scenario requires 50% of the MSW to be recycled or composted. This will require the set-up of new collection schemes. For an economical recycling, separation of the waste stream at the source is very important. The new collection schemes will be more expansive as well. Against the cost side stand the direct benefits of the collected materials value and the indirect benefits of the avoided damage. The indirect benefits of recycling are estimated at € 185 per tonne MSW ([Coopers and Lybrand, March 1996], [EFTEC, August 1998], this study).
The collection schemes can generally be split in three steps. The cheap first step consists of a bring system. The second step consists of a more intensive bring system, and the expensive third step consists of a kerb side collect system. The operation costs of these schemes depend on the population density in the region. We discerned rural and urban in the belief that a more detailed split-up would hardly change the results. This calculation assumes cost-optimal development of recycling along the cost-curves outlined below which might not necessarily correspond to the choices made in the countries. The recycling costs – collection, transport, reprocessing - vary for the actual kind of waste collected.



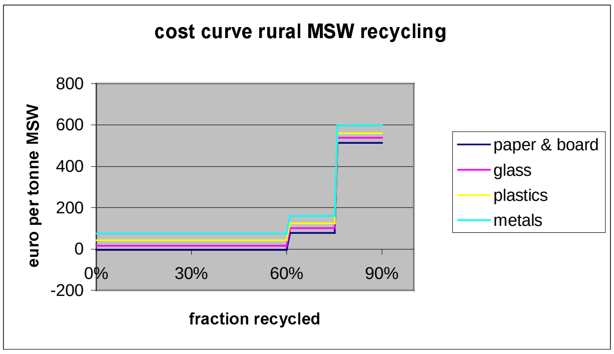


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Figure A: Marginal cost curves for MSW as use in this study. For the first 60%, a scheme for recycling of paper and board in urban areas has net profits. Recycling more than 75% of any MSW stream is associated with marginal costs over € 300 per tonne and does not pass the cost benefit test as benefits are estimated at € 185 per tonne.

The first step, simple bring system, recycling of paper and board even gives a net profit, while for plastics, glass, and metals any recycling scheme is associated with costs. Figure A gives the marginal cost curves for rural and urban MSW recycling, as used for this study.

For this study, TME updated the costs curves derived in a previous study [Coopers and Lybrand, March 1996] which was based on 1993 data. However, recycling cost estimates should be handled with care. They depend on a variety of operational factors such as the exact materials covered by a scheme and the technical and organisational choices of the collection scheme in the Member States. For comparison with other recycling costs estimates, Table 1.A presents recent recycling data for 4 Member States [SOFRES, 2000]. The recycling costs are aggregated over the four waste streams and urban/rural regions and split into municipal waste and packaging waste. The cost curves in Figure A consider municipal waste including packaging waste. Despite the fact that the studies use different indicators, there seems to be reasonable agreement between Figure A and Table 1.A, except for plastics.

For low recycling rates, SOFRES recycling cost data seem higher (€ 26-60 per tonne) than the ones used in this study (e.g. € 11 per tonne glass). For high rates there seems to be a smaller difference although some of the SOFRES data show considerable differences from country to country (e.g. only € 7 per tonne glass in the Netherlands at a recycling rate of 84%). Financing need for household packaging waste in Germany ranges from € 82 to 1654 per tonne of sorted waste for 63% to 91% recycling (Table 1.A), while the cost curve indicates that recycling costs for these recycling rates are between € 68 to 357 per tonne in urban areas and higher in rural areas.

A full assessment of the differences between the studies' results requires the comparison of the exact economic parameters used in the studies.

Table 1.A. Financing need and recycling rates in 1998 for 4 Member States of the EU.

	France		Germany		Nether-lands		United Kingdom	
	financing need €/t	Recycling rate %	financing need €/t	recycling rate %	financing need €/t	Recycling rate %	financing need €/t	recycling rate %
Glass	26	48	82	83	7	84	60	26
Plastics	1294	5	1654	69	n.a.	n.a.	n.a.	n.a.
Paper/board	362	11	147	91	70	46	n.a.	n.a.
Tinplate	89	45	369	77	27	70	n.a.	n.a.
Aluminium	-50	7	790	63	n.a.	n.a.	-576	28

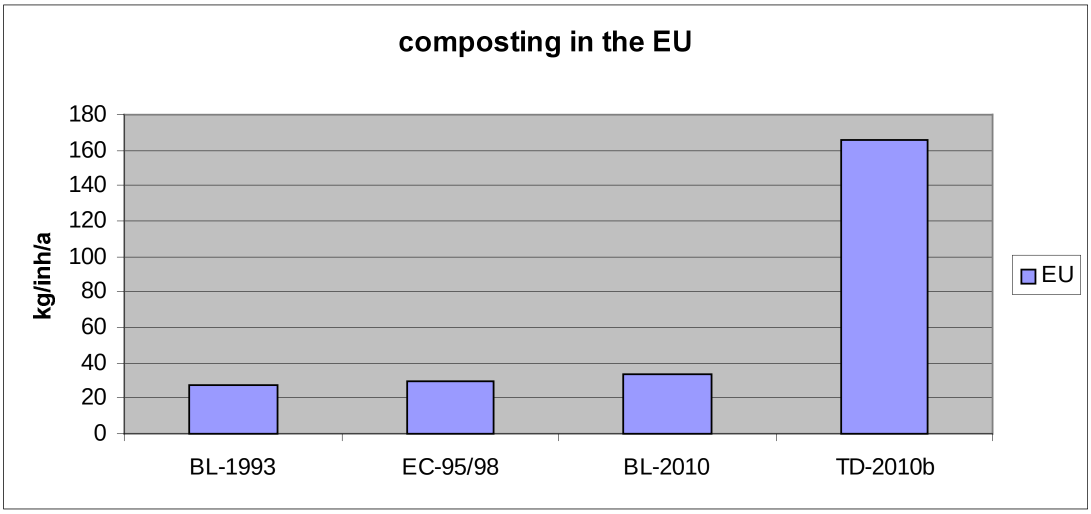
Source: [SOFRES, 2000]

It is shown that the financing need of recycling systems is not (linearly) increasing with increasing recycling rates. Apparently, the financing need of a system for a given recycling rate [is country specific and] depends on a variety of factors such as the set up schedule and geographical scope of collection schemes, technical and organisational choices.

To assess the uncertainty in composting data [Fumigalli, 2000] presented an update of the 1993 data by [Cooper and Lybrand, March 1996]. Figure 1 compares these data and the Baseline projection and the maximum composting scenario discussed in section 2.4. It displays the composting in the EU in kg biodegradable collected per inhabitant per year. The amount of potential arisings ranges to some 160 kg/inh/a, while, in the nineties some 30 kg/inh/a was collected. Without new initiatives biodegradable arisings remain at this level in 2010.

Considering scenario TD-2010b (which implies an effort for maximal Composting, maximal Recycling), it can be shown that there is a huge potential for composting. The EC-96/98 data, which you sent us, show that little progress has been made since 1993, especially if one bears in mind that these data include home composting. The EC-96/98 data are an overestimate of the amount biodegradable MSW collected.

Figure 1 Composting in the EU (kg/inh/a). The Technology Driven (TD) scenario, b version maximum composting and recycling, demonstrates the huge potential for composting of biodegradable municipal solid waste. Recent data (EC-95/98) falls well in the range spanned by the Baseline 1993 (BL-1993) and Baseline 2010 (BL-2010), though for individual Member States deviations may exist.


composting in the EU
kg/inh/a
180
160
140
120
100
80
60
40
20
0
BL-1993
EC-95/98
BL-2010
TD-2010b
EU

1.2.4 Scenario's

In this section, the construction of the scenario's have been outlined. For each scenario the following aspects have been considered:

- Distribution of the six MSW fractions (organic, paper, glass, plastics, metal and other) over the five MSW treatment/disposal methods (Composting, Recycling, Incineration WTE, Incineration and Landfill);
- Interpretation of the different underlying Directives: Packaging and Packaging Waste Directive and Landfill Directive.

assessment of BL-1993

The distribution of MSW-arising over the five treatment/disposal methods for the EU-15 has been based on [Coopers and Lybrand, March 1996]. To distribute the six MSW fractions over the five MSW treatment/disposal methods, the following assumptions have been made:

- Composting is coupled to the organic fraction;
- Recycling is coupled to the fractions paper and glass. Therefore the recycling rate is determined by dividing the total Recycling percentage presented in [Coopers and Lybrand, March 1996] by the sum of the MSW fractions paper and glass. The recycling rate corresponds to the Recycling percentage of the recyclable fractions paper and glass;
- Incineration WTE, Incineration and Landfill are coupled to all six fractions. First the total share of MSW remaining after Composting and Recycling is determined (<100%). The percentages for Incineration WTE and Incineration based on [Coopers and Lybrand, March 1996] are corrected by dividing them by the remaining share and applied to all six fractions. The percentage of Landfill for each fraction is finally calculated by subtracting the percentages of Composting, Recycling, Incineration WTE and Incineration from 100%.

assessment of BL-2010

Compared to BL-1993, the Packaging and Packaging Waste Directive is included in the BL-2010 scenario. The interpretation of this Directive is as follows:

- Focus on the MSW-fractions paper, glass, plastics and metal;
- Minimal 15% for each fraction and 25-45% recycling for the total (four) packaging fractions.

Besides the influence of the Packaging and Packaging Waste Directive on the MSW treatment method Recycling, there are no differences between the BL-1993 and BL-2010 scenario's concerning the other MSW treatment/disposal methods, meaning:

- No change in Composting compared to BL-1993 (exclusion of the Landfill Directive!);
- The distribution of the remaining amount of waste over the MSW disposal methods Incineration WTE, Incineration and Landfill has been done in the same way as in BL-1993.

assessment of TD-2010

Two assessments have been carried out for TD-2010, namely:

a. Maximal Incineration with energy recovery (Incineration WTE): TD-2010a;
b. Maximal Composting and Recycling: TD-2010b.

assessment of TD-2010a

Compared to BL-2010, the focus is on maximal Incineration WTE. Translated to the MSW treatment/disposal methods, this focus results in the following:

- No change in Composting and Recycling;
- Incineration WTE: the remaining amounts of the fractions Organic, Paper and Plastic and the complete amounts of the fractions Glass, Metals and Other are 100% incinerated with energy recovery;
- No MSW to Incineration nor to (direct) Landfill. The incineration ashes, coming from the disposal method Incineration WTE, are landfilled (indirectly).

assessment of TD-2010b
Compared to BL-2010, the focus in on maximal Composting and maximal Recycling. Translated to the MSW treatment/disposal methods, this focus results in the following:
- Maximal Composting. 90% of the organic fraction will be composted;
- Maximal Recycling. 90% (corresponding to the three marginal steps) of the fractions Paper, Glass, Plastic and Metal will be recycled;
- The distribution of the remaining amount of waste over the MSW disposal methods Incineration WTE, Incineration and Landfill has been done in the same way as in BL-2010.

assessment of AP-2010
In AP-2010, the Landfill Directive has been included and the attention is focused on prevention of MSW and on optimal recycling.
The translation of the Landfill Directive is as follows:
- Reduction of the landfilled biodegradable fraction (organic and paper) with 75% compared to BL-1993. Due to the autonomous growth of landfilled organic and paper waste (see BL-2010), the reduction percentage in AP-2010 is larger than 75%. The distribution of the reduction percentage over the fractions organic and paper is as follows: 75% Recycling of paper (corresponding to optimal, two marginal (bring) steps, Recycling!) and the rest by Composting of the organic fraction.

The assumed prevention percentages have been determined in co-operation with the RIVM/EFTEC and are based on the Norwegian results of a virgin tax on the packaging materials paper and plastic [Bruvoll 1998]: a tax of 15% of the price of virgin materials declines the packaging waste by 8.5% over a 10 year period (2000-2010).

Besides inclusion of the Landfill Directive and prevention of MSW arising, the focus is on optimal Recycling. Translated to the MSW-treatment/disposal methods in the AP-2010 scenario this focus results in the following:
- Recycling: 75% (two marginal steps of the bringing system) of the fractions paper, glass, plastic and metals is recycled. The average recycling costs (of two marginal steps) are lower than costs for landfilling. Exceptions are the rural fractions of plastics and metals;
- Incineration WTE. Besides regular Incineration WTE (see BL-2010), all Incineration without energy recovery are upgraded to Incineration WTE;
- No Incineration (without energy recovery) anymore;
- The distribution of the remaining amounts of waste over the MSW disposal methods Incineration WTE (plus Incineration!) and Landfill has been done in the same way as in BL-2010.

Determination of prevention costs
From [Bruvoll, 1998] has been derived that a tax of 15% will result in a prevention of packaging material of 8.5% in 10 years (starting in 2000 and harvesting in 2010). To determine the prevention costs (€ per tonne prevented), the following approach has been followed:
- Extra costs: (0,915 * 1,15 – 1) * Price of virgin materials (tax revenue as extra costs);
- Prevented waste: 8.5%
- Prices of virgin materials (expressed in $€_{1997}$ per tonne) are derived from [CBS, 1994]:
  - € 0.5 per tonne paper pulp;
  - € 832 per tonne polyethylene;
- Resulting prevention costs (expressed in € per tonne prevented virgin material):
  - € 0.3 (paper);
  - € 512 (plastics).

1.3 Results

In this section the overall EU-15 results concerning MSW-arisings and MSW treatment/disposal costs are presented for the five scenario's BL-1993, BL-2010, TD-2010a, TD-2010b and AP-2010. The tables with detailed, country-specific information are presented in Annex I (MSW-arisings), Annex II (MSW treatment/disposal costs) and Annex III (specific MSW treatment/disposal costs).

In table 1.1, the distribution of MSW-arising per capita in the EU-15 over the five treatment/disposal methods is presented for the scenario's BL-1993, BL-2010, TD-2010a, TD-2010b and AP-2010.

Table 1.1 Distribution of MSW-arising per capita in the EU-15 over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration and Landfill (direct and indirect) for the BL-1993, BL-2010, TD-2010a, TD-2010b and AP-2010 scenario's

Scenario[1]	*Prevention (kg/capita/a)*	*Treatment/disposal methods (kg/capita/a)*						***Total (kg/capita/a)***	
		Composting	Recycling	Incineration		Landfill		**Exclusive Indirect Landfill**	**Inclusive Indirect Landfill**
				WTE	no WTE	Direct	Indirect		
BL-1993		28	53	74	43	304	30	**503**	**534**
BL-2010		32	115	83	40	321	31	**590**	**622**
TD-2010a		32	115	443	0	0	110	**590**	**701**
TD-2010b		162	254	49	29	96	21	**590**	**611**
AP-2010	18	148	198	75	0	152	27	**573**	**600**

Based on table 1.1 (and Annex I), the following can be stated about the MSW-arising in the BL-1993, BL-2010, TD-2010a, TD-2010b and AP-2010 scenario's:

- The MSW-arising increases from 503 to 590 kg/capita/year over the period 1993-2010 (+23%);
- In AP-2010 scenario the MSW-arising increases till 573 kg/capita/year (+18%);
- When landfilling of incineration ashes is included the MSW-arising increases from 534 to 701 kg/capita/year for the scenario TD-2010 a (+38%) while in the scenario AP-2010 the increase is (+18%).

In table 1.2, the distribution of the additional MSW-treatment/disposal costs in the EU-15 over the five treatment/disposal methods is presented for the scenario's BL-1993, BL-2010, TD-2010a, TD-2010b, AP-2010 (with prevention) and AP-2010 (without prevention).

[1] BL-2010 includes the Packaging Directive, TD-2010a focuses on maximal Incineration with energy recovery, TD-2010b focuses on maximal Composting and maximal Recycling and AP-2010 includes prevention of MSW-arising, the Landfill Directive and optimal Recycling.

Table 1.2 Distribution of MSW-treatment/disposal costs in the EU-15 over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration and Landfill (direct and indirect) for the BL-1993, BL-2010, TD-2010a, TD-2010b, AP-2010 (with prevention) and AP-2010 (without prevention) scenario's

Scenario	*Prevention (bn.€ per a)*	*Treatment/disposal methods (bn.€ per a)*						***Total (bn.€ per a)***	
		Composting	Recycling[2]	Incineration		Landfill		**Exclusive Indirect Landfill**	**Inclusive Indirect Landfill**
				WTE	no WTE	Direct	Indirect		
BL-1993	0,0	0,8	0,	2,8	2,0	5,9	0,6	11,5	12,0
BL-2010	0,0	1,0	0,2	3,2	1,9	6,4	0,6	12,7	13,3
TD-2010a	0,0	1,0	0,2	1,7	0,0	0,0	2,2	18,5	20,7
TD-2010b	0,0	4,8	7,7	1,9	1,4	1,9	0,4	17,7	18,1
AP-2010 (with prevention)	0,2	4,4	1,4	2,9	0,0	3,0	0,5	12,0	12,5
AP-2010 (w/o prevention)	0,0	4,5	1,4	2,9	0,0	3,1	0,5	11,9	12,5

Based on table 1.2 (and Annex II), the following can be stated about the MSW treatment/disposal costs in the BL-1993, BL-2010, TD-2010a, TD-2010b, AP-2010 (with) and AP-2010 (without) scenario's:

- In the BaseLine scenario, the total annual treatment/disposal costs increase with €1.3 billion to €13.3 billion per year in the period 1993-2010;
- For the two TD-2010 scenario's the MSW treatment/disposal costs are much higher than in the BL-2010 scenario. Especially TD-2010a (maximal Incineration WTE) is so costly due to indirect Landfill costs;
- For the AP-2010 scenario's the MSW treatment/disposal costs are lower than under the BL-2010 scenario. There is hardly an overall difference between AP with and without prevention. As is shown in table 1.3, the annual treatment/disposal costs per capita decrease due to shift from Landfill to Recycling and Composting. Recycling (two marginal steps) is cheaper while Composting is slightly more expensive than Landfill. Overall annual treatment/disposal costs per capita decrease.

[2] For comparison, the estimated recycling costs on the basis of empirical information for all packaging recycling in EU 15 in the year 1998 are evaluated at 5.3 bn € by PriceWaterhouseCoopers 1998, The Facts: A European Cost/Benefit Perspective, p.9; also see footnote 2.

In table 1.3 the MSW treatment/disposal costs per capita in each Member State are presented for the five scenario's.

Table 1.3 MSW treatment/disposal costs per capita in the EU-15 countries for the BL-1993, BL-2010, TD-2010a, TD-2010b and AP-2010 scenario.

Country	*Scenario's (including indirect Landfill) (€ per capita/a)*					
	BL-1993	BL-2010	TD-2010a	TD-2010b	AP-2010 (with prevention)	AP-2010 (without prevention)
Austria	34.4	36.7	52.1	51.0	37.1	37.1
Belgium	39.7	39.3	46.4	41.3	29.5	29.5
Denmark	37.0	50.4	58.1	58.0	44.7	44.8
Finland	31.8	36.7	42.1	43.1	32.9	33.0
France	51.5	42.7	53.8	49.3	34.6	34.5
Germany	34.5	39.2	56.7	53.2	39.4	39.3
Greece	21.1	23.7	48.7	40.1	27.8	27.7
Ireland	27.2	36.3	74.7	59.3	42.0	41.6
Italy	26.5	26.9	52.3	42.3	26.7	26.7
Luxembourg	34.2	47.4	56.7	56.6	44.7	44.9
Netherlands	34.0	40.6	56.4	51.9	38.3	38.2
Portugal	22.8	24.8	46.7	37.3	26.2	26.1
Spain	21.2	22.9	41.5	35.5	23.8	23.7
Sweden	33.3	39.8	45.8	45.9	35.4	35.5
United Kingdom	26.6	31.4	61.1	47.9	28.3	28.4
EU-15	**32.6**	**34.4**	**53.5**	**46.9**	**32.3**	**32.3**

Based on table 1.3 (and Annex III), the following can be stated about the country specific MSW treatment/disposal costs in the BL-1993, BL-2010, TD-2010a, TD-2010b, AP-2010 (with prevention) and AP-2010 (without prevention) scenario's:

- The EU-15 MSW treatment/disposal costs per capita in the Baseline scenario increases slightly in the period 1993-2010. Exceptions are two countries: only for Belgium and France the specific MSW treatment/disposal costs for BL-2010 are lower than for BL-1993. As can be seen in Annex 3 the overall specific treatment/disposal costs (€ per tonne) lowers substantially for Belgium while for France there is only a small increase of generated MSW in the period 1993-2010 (see Annex 1). The average MSW increase in the EU-15 is 23,0% while the increase for France is only 2,2%. A big part of this MSW increase is recycled in the BL-2010 scenario for the low treatment/disposal cost of €7 per tonne;
- The EU-15 MSW treatment costs per capita in the AP scenario are lowest. As can been seen in Annex 1 the increase of generated (and disposed) MSW is small for this scenario (prevention is cheap!). Besides an optimisation of the treatment option Recycling (only €18 per tonne) results in lower overall treatment/disposal costs per capita
- The average EU-15 treatment/disposal costs vary from €54 (AP-2010) to €55 (BL-2010), €61 (BL-1993) and to €77 per tonne MSW (TD-2010b). So in the BaseLine scenario, average EU-15 treatment/disposal costs decreases with 10% in the period 1993-2010. This decrease is caused by a larger amount of MSW recycled and a smaller amount incinerated WTE and landfilled in the BL-2010 scenario. Recycling (still limited to the first marginal step) is much cheaper than Landfill and Incineration WTE is more expense than Landfill;
- The average EU-15 treatment/disposal cost for the TD-2010a scenario is €76 per tonne MSW. The increase in comparison to BL-2010 is caused by the shift from Landfill (€52 per tonne MSW) to Incineration WTE (€101 per tonne MSW). The extra landfill (from the incineration ashes) lowers the total treatment price (extra relatively cheap (indirect) Landfill);

- The average EU-15 treatment/disposal cost for the TD-2010b scenario is €77 per tonne MSW. The increase in comparison to BL-2010 is caused by the shift from Landfill (€52 per tonne MSW) to Composting (€77 per tonne MSW) and Recycling (€78 per tonne MSW). The cost of Recycling is so high (compared to Recycling in the other scenario's) due to the application of all three marginal steps. The cost of the third marginal Recycling step varies from €328 per tonne for collected paper in urban areas to €583 per tonne for collected metals in rural areas.

Comparison of pressure reductions by 2010

In general, the MSW-arising has grown in the period 1993-2010 (see table 1.1 and Annex I). This growth of MSW-arising is caused by three trends observable in this period, namely:

- Growth of total population. Based on population data from [NTUA, 1998], it can be seen that the total population growth in the EU-15 is 4,8% in the period 1993-2010;
- Growth of MSW-arising per capita caused by growth of GDP in the period 1993-2010. The average MSW-arising per capita in the EU-15 increases from 503 to 590 kg MSW/capita/year;
- Small growth of landfilled amount of incineration ashes per capita. This trend varies along the different scenario's. For AP-2010 and TD-2010b the share of indirect landfill decreases, for BL-2010 is stabilises while for TD-2010a the share increases enormously.

Only in the AP-2010 scenario this increase of annual MSW-arising per capita is prevented a little bit by taxation of the packaging materials paper and plastic resulting in an average MSW-arising of 573 kg MSW/capita/year (excluding indirect Landfill!).

Besides the relative small prevention of MSW, attention is paid to pushing the MSW treatment/disposal methods upwards in the Waste management hierarchy meaning less Landfill and Incineration (without energy recovery) and more Composting, Recycling and Incineration WTE. Compared to BL-2010, the share of Landfill and Incineration has decreased from 63% to 16% (TD-2010a), to 24% (TD-2010b) and to 29% (AP-2010).

Efficiency

The average EU-15 prevention is 3,0%. More specifically the prevention is 8,5% for the packaging fractions paper and plastics. Because of the difference in MSW-compositions over the Member States, the overall prevention percentages vary from 2,3% in Ireland to 3,3% in the United Kingdom.

Analysis of spillover of policies from/to other environmental issues

The reduction of organic and paper waste to Landfill has direct influence on the CH_4-emissions (environmental issue of Climate Change) from landfills. Application of the AP-2010 waste scenario results in decrease of landfilled organic and paper waste of 55 Mtonne/a in 2010. Translated to methane emissions, the decrease of organic and paper waste to the disposal option Landfill results in a decrease in 2010 of 3,1 Mtonne CH_4/year (65 Mtonne CO_2-equivalents/year).

Shift from Landfill to Incineration WTE has influence on the input of (fossil) fuels of the sector Power generation, resulting in less CO_2-emissions (environmental issue Climate Change) and other emission types (environmental issues Acidification and Urban Stress). In table 1.4 the sustainable energy potentials (defined as the energy product from the MSW treatment option Incineration WTE) in the Member States is presented for the scenario's BL-1993, BL-2010, TD-2010a, TD-2010b and AP-2010.

Table 1.4 Sustainable energy potential by applying the MSW treatment option Incineration WTE in the EU-15 countries for the BL-1993, BL-2010, TD-2010a, TD-2010b and AP-2010 (with prevention) scenario.

Country	*Sustainable energy potential (PJ/a)*				
	BL-1993	BL-2010	TD-2010a	TD-2010b	AP-2010 (with prevention)
Austria	1	1	3	1	1
Belgium	1	1	4	0	1
Denmark	1	2	3	1	1
Finland	1	1	2	0	1
France	4	4	24	2	8
Germany	11	13	35	8	10
Greece	0	0	4	0	0
Ireland	0	0	2	0	0
Italy	0	0	23	0	1
Luxembourg	0	0	0	0	0
Netherlands	2	2	7	1	2
Portugal	0	0	3	0	0
Spain	0	0	12	1	0
Sweden	2	3	4	1	1
United Kingdom	1	1	29	1	2
EU-15	**25**	**29**	**154**	**17**	**26**

Based on table 1.4, the following can be stated about the sustainable energy potential generated by the MSW treatment option Incineration WTE in the BL-1993, BL-2010, TD-2010a, TD-2010b and AP-2010 scenario's:

- The EU-15 sustainable energy potentials for the scenario's BL-1993, BL-2010 and AP-2010 (with prevention) are more or less equal. For the scenario TD-2010a (maximal Incineration WTE) this sustainable energy potential is around 5 times higher;
- The environmental/economic effect of applying this sustainable energy potential depends on the fuel mix per Member State.

1.4 Conclusions

Potential for solving the environmental issue Waste Management

In the AP scenario the application of the Virgin materials tax on paper and plastic results in an overall prevention of 3%. Compared to the MSW-arising in EU-15 of BL-1993, there is still an increase of nearly 13%. So the attempt to decrease the MSW-arising in the period 1993-2010 has failed. Besides the percentages for paper and plastic prevention, valid for Norway, are extrapolated to all EU-countries.

The shift in MSW treatment/disposal methods from Landfill to more desirable options like Incineration WTE (still causing substantial indirect Landfill), Recycling and Composting is successful in a cost-effective way in the AP-scenario. Compared to BL-1993, Landfill (direct and indirect) decreases with 155 kg/capita/year, Incineration (without energy recovery) vanishes. For even decreasing disposal costs per capita (-1%!) Landfill and Incineration are replaced by Recycling and Composting.

Shifting from Incineration without to Incineration with energy recovery is considered to be cost-effective. One should bear in mind that no retrofit costs have been included. So no old Incinerators without energy recovery are upgraded to Incinerators with energy recovery. This upgrading step could have been less cost effective.

Advantage of AP-2010 over BL-2010

Concerning the MSW treatment/disposal under the two scenario's, the advantages of AP-2010 over BL-2010 are the following:

- Prevention policies (taxation of packaging materials) result in an average EU-15 reduction of MSW-arising of 3,5%;
- The implementation of the Landfill Directive, optimal Recycling (75% for the fractions paper, glass, plastic and metal) and Incineration WTE (upgrading of plain Incineration to Incineration WTE): from 52% in BL-2010 (direct Landfill) to 25% in AP-2010. Composted and recycled amounts of MSW are more than doubled in AP-2010.

Costs, benefits, feedback

Besides a smaller amount of MSW to be treated under AP-2010, the MSW treatment/disposal costs are €0,8 billion per year lower compared to BL-2010. Compared to the situation in 1993 (BL-1993) the costs are around €0,5 billion per year higher for AP-2010 (with prevention). In table 1.5 costs, benefits and the difference between costs and benefits are presented for the scenario's TD-2010a, TD-2010b, AP-2010 (with prevention) and AP-2010 (without prevention). All presented costs and benefits are compared to costs and benefits made in BL-2010.

Table 1.5 Costs, benefits and difference between costs and benefits for the scenario's TD-2010a, TD-2010b, AP-2010 (with prevention) and AP-2010 (without prevention) compared to BL-2010

Scenario	*Costs (€ billion per a)*		*Benefits (€ billion per a)*		***Difference (€ billion per a)***	
	(excl. Extra Landfill)	(incl. Extra Landfill)	(excl. Extra Landfill)	(incl. Extra Landfill)	**(excl. Extra Landfill)**	**(incl. Extra Landfill)**
TD-2010a	5.8	7.4	-2.5	-2.8	**8.4**	**10.2**
TD-2010b	5.0	4.8	10.3	10.3	**-5.2**	**-5.5**
AP-2010 (with prevention)	-0.7	-0.8	8.7	8.7	**-9.4**	**-9.5**
AP-2010 (without prevention)	-0.7	-0.8	7.2	7.2	**-7.9**	**-8.0**

Based on table 1.5, the following can be stated about the costs, benefits and difference compared to BL-2010 for the scenario's TD-2010a, TD-2010b, AP-2010 (with prevention) and AP-2010 (without prevention):

- Only in the TD-2010a scenario, the benefits are smaller than in the BL-2010 scenario resulting in negative additional benefits (net environmental costs). Combined with the highest additional costs, this results in net additional costs compared to BL-2010
- Both the AP-2010 scenario's and the TD-2010b scenario have net additional benefits compared to BL-2010 which are highest for the AP-2010 scenario with prevention;
- Only in the AP-2010 scenario's, the costs are smaller than in the BL-2010 scenario. As explained in table 1.3 this is mainly due to the beneficial shift from Landfill to Composting/Recycling.

Spillover to other environmental issues

The AP-2010 has, by means of applying the Landfill Directive, a large influence on the amount of organic and paper waste landfilled and therefore influence on the methane emissions resulting from the emission source Landfill (anaerobic digestion of organic and paper waste on landfills). In case the Landfill Directive is fully implemented it would mean that no further CH_4-reduction measures are required to comply the target set in the environmental issue Climate Change for non-CO_2 gasses (-8%).

Another aspect related to the environmental issue Climate Change is the reduction of CO_2-emissions due to implementation of Incineration WTE. Especially in the TD-2010a scenario (maximal Incineration WTE) the annual sustainable energy potential for the EU-15 increases with 130 PJ compared to BL-2010. In the AP-2010 scenario the sustainable energy potential is even slightly lower than in BL-2010.

1.5 References

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1.6 Annex I[3]. Distribution of MSW-arising over treatment/disposal methods

In table I.1 to I.6, the distribution of MSW-arising over the five treatment/disposal methods is presented for the EU-15 countries for the following scenario's:

- Table I.1: BL-1993 scenario;
- Table I.2: BL-2010 scenario;
- Table I.3: TD-2010a scenario (maximal Incineration WTE);
- Table I.4: TD-2010b scenario (maximal Composting and Recycling);
- Table I.5: AP-2010 scenario (with prevention);
- Table I.6: AP-2010 scenario (without prevention).

Table I.1 Distribution of MSW-arising over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the BL-1993 scenario

Country	*Treatment*/disposal *methods*						***Total***	
	Composting	Recycling	Incineration		Landfill		**Exclusive**	**Inclusive**
			WTE	no WTE	Direct	Indirect	**Indirect Landfill**	**Indirect Landfill**
	(kt/a)	(kt/a)	(kt/a)	(kt/a)	(kt/a)	(kt/a)	**(kt/a)**	**(kt/a)**
Austria	419	922	1090	0	1761	305	**4192**	**4497**
Belgium	96	337	818	1683	1876	434	**4809**	**5243**
Denmark	26	578	1525	0	500	274	**2629**	**2903**
Finland	21	461	1215	0	398	218	**2095**	**2313**
France	2057	1714	4799	10284	15426	4232	**34281**	**38513**
Germany	4710	10362	12245	0	19781	3467	**47098**	**50565**
Greece	0	256	0	0	4007	0	**4263**	**4263**
Ireland	0	17	0	0	1732	0	**1749**	**1749**
Italy	0	1054	0	1581	23718	360	**26353**	**26713**
Luxembourg	2	53	89	0	45	16	**188**	**204**
Netherlands	1167	1418	2085	250	3419	554	**8339**	**8893**
Portugal	363	36	0	0	3232	0	**3631**	**3631**
Spain	1426	143	428	285	11981	139	**14263**	**14402**
Sweden	40	873	2303	0	754	414	**3970**	**4384**
United Kingdom	0	1393	836	1950	23673	819	**27851**	**28670**
EU-15	**10328**	**19616**	**27432**	**16034**	**112302**	**11230**	***185711***	***196942***

[3] For individual member states the baseline projection concerning composting for 2010 already underestimates the state of the art for the year 2000 in some cases. This is due to the methodology applied which extrapolates from the Cooper & Lybrand data. See section 2.3 Major uncertainties. This will not change the main conclusion that there is a huge potential for composting in the EU.

Table I.2 Distribution of MSW-arising over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the BL-2010 scenario

Country	*Treatment*/disposal *methods*						***Total***	
	Composting	Recycling	Incineration			Landfill	**Exclusive**	**Inclusive**
			WTE	no WTE	Direct	Indirect	**Indirect Landfill**	**Indirect Landfill**
	(kt/a)	(kt/a)	(kt/a)	(kt/a)	(kt/a)	(kt/a)	**(kt/a)**	**(kt/a)**
Austria	480	1164	1207	0	1950	332	**4801**	**5133**
Belgium	111	931	841	1731	1929	413	**5543**	**5956**
Denmark	38	890	2154	0	706	382	**3787**	**4169**
Finland	27	623	1508	0	494	267	**2651**	**2918**
France	2103	6011	4237	9080	13620	3838	**35052**	**38890**
Germany	5883	14266	14789	0	23890	4127	**58828**	**62955**
Greece	0	744	0	0	4850	0	**5594**	**5594**
Ireland	0	359	0	0	2414	0	**2773**	**2773**
Italy	0	4919	0	1602	24033	358	**30554**	**30912**
Luxembourg	3	93	146	0	74	26	**317**	**343**
Netherlands	1560	2112	2707	325	4440	707	**11144**	**11851**
Portugal	459	563	0	0	3572	0	**4594**	**4594**
Spain	1809	2709	457	305	12807	139	**18087**	**18226**
Sweden	52	1218	2948	0	966	522	**5183**	**5705**
United Kingdom	0	7735	1002	2338	28390	958	**39465**	**40423**
EU-15	**12525**	**44338**	**31996**	**15381**	**124133**	**12069**	***228373***	***240442***

Table I.3 Distribution of MSW-arising over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the TD-2010a scenario (maximal Incineration WTE)

Country	*Treatment*/disposal *methods*						***Total***	
	Composting	Recycling	Incineration		Landfill		**Exclusive Indirect Landfill**	**Inclusive Indirect Landfill**
			WTE	no WTE	Direct	Indirect		
	(kt/a)	(kt/a)	(kt/a)	(kt/a)	(kt/a)	(kt/a)	**(kt/a)**	**(kt/a)**
Austria	480	1164	3157	0	0	869	**4801**	**5670**
Belgium	111	931	4501	0	0	722	**5543**	**6265**
Denmark	38	890	2859	0	0	507	**3787**	**4294**
Finland	27	623	2002	0	0	355	**2651**	**3006**
France	2103	6011	26937	0	0	7764	**35052**	**42816**
Germany	5883	14266	38679	0	0	10795	**58828**	**69623**
Greece	0	744	4850	0	0	699	**5594**	**6293**
Ireland	0	359	2414	0	0	471	**2773**	**3244**
Italy	0	4919	25635	0	0	5721	**30554**	**36275**
Luxembourg	3	93	220	0	0	39	**317**	**356**
Netherlands	1560	2112	7472	0	0	1742	**11144**	**12886**
Portugal	459	563	3572	0	0	776	**4594**	**5370**
Spain	1809	2709	13569	0	0	2478	**18087**	**20565**
Sweden	52	1218	3913	0	0	694	**5183**	**5877**
United Kingdom	0	7735	31730	0	0	9097	**39465**	**48562**
EU-15	**12525**	**44338**	**171510**	**0**	**0**	**42728**	***228373***	***271101***

Table I.4 Distribution of MSW-arising over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the TD-2010b scenario (maximal Composting and Recycling)

Country	*Treatment*/disposal *methods*						***Total***	
	Composting	Recycling	Incineration		Landfill		**Exclusive Indirect Landfill**	**Inclusive Indirect Landfill**
			WTE	no WTE	Direct	Indirect		
	(kt/a)	(kt/a)	(kt/a)	(kt/a)	(kt/a)	(kt/a)	**(kt/a)**	**(kt/a)**
Austria	1383	2031	723	0	664	218	**4801**	**5019**
Belgium	2145	2395	248	511	245	184	**5543**	**5727**
Denmark	1261	1568	791	0	167	268	**3787**	**4055**
Finland	883	1098	554	0	117	188	**2651**	**2839**
France	6625	15458	2373	5085	5512	2790	**35052**	**37842**
Germany	16678	24884	8945	0	8321	2733	**58828**	**61561**
Greece	2467	1913	436	0	778	0	**5594**	**5594**
Ireland	1048	923	191	0	610	0	**2773**	**2773**
Italy	8662	12649	0	2468	6774	237	**30554**	**30791**
Luxembourg	105	131	61	0	19	20	**317**	**336**
Netherlands	3912	4614	1375	165	1079	398	**11144**	**11542**
Portugal	1612	1447	312	0	1222	0	**4594**	**4594**
Spain	7179	6967	910	607	2424	78	**18087**	**18165**
Sweden	1726	2146	1082	0	229	367	**5183**	**5550**
United Kingdom	7104	19890	1019	2377	9075	569	**39465**	**40034**
EU-15	**62789**	**98114**	**19021**	**11212**	**37236**	**8049**	***228373***	***236422***

Table I.5 Distribution of MSW-arising over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the AP-2010 (with prevention) scenario

Country	*Prevention*	*Treatment*/disposal *methods*						***Total***	
		Composting	Recycling	Incineration		Landfill		**Exclusive Indirect Landfill**	**Inclusive Indirect Landfill**
				WTE	no WTE	Direct	Indirect		
	(kt/a)	(k/a)	(kt/a)	(kt/a)	(kt/a)	(kt/a)	(kt/a)	**(kt/a)**	**(kt/a)**
Austria	135	1213	1591	887	0	975	320	**4666**	**4987**
Belgium	165	1885	1872	964	0	658	255	**5378**	**5633**
Denmark	119	1221	1217	982	0	248	325	**3668**	**3993**
Finland	83	812	852	722	0	182	228	**2568**	**2795**
France	1132	5412	12032	8625	0	7850	3257	**33920**	**37177**
Germany	1650	15226	19499	10700	0	11753	3995	**57178**	**61173**
Greece	138	2262	1491	0	0	1704	0	**5456**	**5456**
Ireland	64	1011	722	0	0	977	0	**2709**	**2709**
Italy	896	7657	9869	788	0	11344	280	**29658**	**29938**
Luxembourg	10	105	105	71	0	26	25	**307**	**331**
Netherlands	313	3649	3610	1777	0	1795	596	**10831**	**11427**
Portugal	113	1466	1121	0	0	1894	0	**4481**	**4481**
Spain	489	6525	5439	353	0	5281	105	**17598**	**17704**
Sweden	163	1608	1666	1394	0	352	445	**5020**	**5465**
United Kingdom	1308	7182	15594	1695	0	13686	707	**38157**	**38863**
EU-15	**6778**	**57234**	**76681**	**28957**	**0**	**58723**	**10538**	***221595***	***232133***

Table I.6 Distribution of MSW-arising over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the AP-2010 (without prevention) scenario

Country	*Prevention*	*Treatment*/disposal *methods*						***Total***	
		Composting	Recycling	Incineration		Landfill		**Exclusive Indirect Landfill**	**Inclusive Indirect Landfill**
				WTE	no WTE	Direct	Indirect		
	(kt/a)	(k/a)	(kt/a)	(kt/a)	(kt/a)	(kt/a)	(kt/a)	**(kt/a)**	**(kt/a)**
Austria		1238	1692	892	0	979	320	**4801**	**5121**
Belgium		1918	1995	969	0	661	255	**5543**	**5798**
Denmark		1245	1307	987	0	249	325	**3787**	**4112**
Finland		829	915	725	0	183	228	**2651**	**2879**
France		5613	12882	8668	0	7890	3257	**35052**	**38309**
Germany		15526	20737	10753	0	11812	3995	**58828**	**62823**
Greece		2285	1594	0	0	1714	0	**5594**	**5594**
Ireland		1019	770	0	0	984	0	**2773**	**2773**
Italy		7833	10541	791	0	11389	280	**30554**	**30834**
Luxembourg		107	112	72	0	26	25	**317**	**341**
Netherlands		3708	3845	1786	0	1805	596	**11144**	**11740**
Portugal		1486	1206	0	0	1902	0	**4594**	**4594**
Spain		6607	5806	356	0	5319	105	**18087**	**18192**
Sweden		1641	1788	1400	0	353	445	**5183**	**5628**
United Kingdom		7459	16575	1700	0	13731	707	**39465**	**40172**
EU-15		**58513**	**81765**	**29098**	**0**	**58997**	**10538**	***228373***	***238911***

1.7 Annex II. Distribution of MSW-treatment/disposal costs over treatment/disposal methods[4]

In table II.1 to II.6, the distribution of MSW-treatment/disposal costs over the five treatment/disposal methods is presented for the EU-15 countries for the following scenario's:

- Table II.1: BL-1993 scenario;
- Table II.2: BL-2010 scenario;
- Table II.3: TD-2010a scenario (maximal Incineration WTE);
- Table II.4: TD-2010b scenario (maximal Composting and Recycling);
- Table II.5: AP-2010 scenario (with prevention);
- Table II.6: AP-2010 scenario (without prevention).

Table II.1 Distribution of MSW-treatment/disposal costs (million €/year) over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the BL-1993 scenario

Country	*Treatment*/disposal *methods*						***Total***	
	Composting	Recycling	Incineration		Landfill		**Exclusive**	**Inclusive**
			WTE	no WTE	Direct	Indirect	**Indirect Landfill**	**Indirect Landfill**
Austria	35	6	115	0	99	17	**255**	**272**
Belgium	7	-2	81	201	92	21	**379**	**400**
Denmark	2	-3	153	0	26	14	**178**	**192**
Finland	2	-2	127	0	22	12	**149**	**161**
France	163	-8	493	1272	822	226	**2743**	**2968**
Germany	359	34	1228	0	1004	176	**2626**	**2801**
Greece	0	-1	0	0	219	0	**218**	**218**
Ireland	0	0	0	0	97	0	**97**	**97**
Italy	0	-4	0	197	1289	20	**1482**	**1502**
Luxembourg	0	1	9	0	2	1	**13**	**14**
Netherlands	89	-7	208	30	172	28	**493**	**521**
Portugal	31	0	0	0	194	0	**225**	**225**
Spain	112	-1	44	35	632	7	**822**	**830**
Sweden	3	-4	233	0	39	21	**270**	**292**
United Kingdom	0	-7	83	236	1193	41	**1505**	**1546**
EU-15	**803**	**3**	**2775**	**1971**	**5902**	**584**	***11454***	***12038***

[4] For individual member states the baseline projection concerning composting for 2010 already underestimates the state of the art for the year 2000 in some cases. This is due to the methodology applied which extrapolates from the Cooper & Lybrand data. See section 2.3 Major uncertainties. This will not change the main conclusion that there is a huge potential for composting in the EU.

Table II.2 Distribution of MSW-treatment/disposal costs (million €/year) over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the BL-2010 scenario

Country	*Treatment*/disposal *methods*						***Total***	
	Composting	Recycling	Incineration		Landfill		**Exclusive Indirect Landfill**	**Inclusive Indirect Landfill**
			WTE	No WTE	Direct	Indirect		
Austria	39	10	126	0	107	18	**283**	**301**
Belgium	8	1	83	206	94	20	**393**	**413**
Denmark	3	-2	216	0	36	19	**252**	**271**
Finland	2	-1	156	0	27	14	**183**	**198**
France	164	42	432	1115	713	201	**2467**	**2668**
Germany	445	78	1476	0	1201	207	**3199**	**3407**
Greece	0	4	0	0	259	0	**262**	**262**
Ireland	0	5	0	0	132	0	**137**	**137**
Italy	0	26	0	198	1284	19	**1508**	**1528**
Luxembourg	0	2	15	0	4	1	**21**	**22**
Netherlands	118	-3	269	39	222	35	**645**	**681**
Portugal	39	6	0	0	207	0	**252**	**252**
Spain	140	23	46	37	664	7	**911**	**918**
Sweden	4	-3	296	0	49	27	**346**	**373**
United Kingdom	0	17	100	282	1419	48	**1817**	**1865**
EU-15	**963**	**203**	**3215**	**1878**	**6419**	**618**	***12677***	***13295***

Table II.3 Distribution of MSW-treatment/disposal cost (million €/year) over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the TD-2010a scenario (maximal Incineration WTE)

Country	*Treatment*/disposal *methods*						***Total***	
	Composting	Recycling	Incineration		Landfill		**Exclusive Indirect Landfill**	**Inclusive Indirect Landfill**
			WTE	no WTE	Direct	Indirect		
Austria	39	10	330	0	0	48	**379**	**427**
Belgium	8	1	443	0	0	35	**452**	**487**
Denmark	3	-2	286	0	0	26	**287**	**312**
Finland	2	-1	207	0	0	19	**208**	**227**
France	164	42	2745	0	0	407	**2952**	**3358**
Germany	445	78	3860	0	0	543	**4383**	**4925**
Greece	0	4	499	0	0	37	**503**	**540**
Ireland	0	5	252	0	0	26	**257**	**283**
Italy	0	26	2640	0	0	306	**2665**	**2971**
Luxembourg	0	2	22	0	0	2	**25**	**27**
Netherlands	118	-3	744	0	0	87	**859**	**946**
Portugal	39	6	384	0	0	45	**429**	**474**
Spain	140	23	1376	0	0	128	**1539**	**1668**
Sweden	4	-3	393	0	0	35	**394**	**429**
United Kingdom	0	17	3158	0	0	455	**3174**	**3629**
EU-15	**963**	**203**	**17338**	**0**	**0**	**2199**	***18504***	***20703***

Table II.4 Distribution of MSW-treatment/disposal costs (million €/year) over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the TD-2010b scenario (maximal Composting and Recycling)

Country	*Treatment* /disposal *methods*						***Total***	
	Composting	Recycling	Incineration WTE	Incineration no WTE	Landfill Direct	Landfill Indirect	**Exclusive Indirect Landfill**	**Inclusive Indirect Landfill**
Austria	112	182	76	0	37	12	**406**	**418**
Belgium	159	168	24	61	12	9	**424**	**433**
Denmark	96	115	79	0	8	14	**298**	**312**
Finland	70	89	57	0	6	10	**223**	**233**
France	517	1261	242	624	289	146	**2934**	**3080**
Germany	1263	1908	893	0	418	137	**4481**	**4618**
Greece	195	163	45	0	41	0	**445**	**445**
Ireland	85	86	20	0	33	0	**224**	**224**
Italy	687	1035	0	306	362	13	**2390**	**2402**
Luxembourg	8	10	6	0	1	1	**26**	**27**
Netherlands	295	345	137	20	54	20	**850**	**870**
Portugal	136	138	34	0	71	0	**378**	**378**
Spain	556	573	92	74	126	4	**1421**	**1425**
Sweden	132	159	109	0	12	19	**411**	**430**
United Kingdom	536	1437	101	286	454	28	**2814**	**2842**
EU-15	**4848**	**7667**	**1915**	**1371**	**1924**	**413**	***17725***	***18138***

Table II.5 Distribution of MSW-treatment/disposal costs (million €/year) over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the AP-2010 (with prevention) scenario

Country	*Prevention*	*Treatment*/disposal *methods* Composting	Recycling	Incineration WTE	Incineration no WTE	Landfill Direct	Landfill Indirect	***Total*** **Exclusive Indirect Landfill**	**Inclusive Indirect Landfill**
Austria	5	98	37	93	0	54	18	**287**	**305**
Belgium	4	140	26	95	0	32	12	**297**	**309**
Denmark	3	93	17	98	0	13	16	**224**	**240**
Finland	2	65	14	75	0	10	12	**165**	**178**
France	42	423	238	879	0	411	171	**1993**	**2163**
Germany	58	1153	354	1068	0	591	201	**3223**	**3424**
Greece	5	179	33	0	0	91	0	**308**	**308**
Ireland	4	82	20	0	0	53	0	**159**	**159**
Italy	25	607	181	81	0	606	15	**1501**	**1516**
Luxembourg	0	8	3	7	0	1	1	**20**	**21**
Netherlands	10	275	60	177	0	90	30	**612**	**641**
Portugal	4	124	27	0	0	110	0	**266**	**266**
Spain	21	506	115	36	0	274	5	**951**	**957**
Sweden	4	123	24	140	0	18	23	**309**	**332**
United Kingdom	26	542	222	169	0	684	35	**1642**	**1678**
EU-15	**213**	**4417**	**1373**	**2917**	**0**	**3037**	**540**	***11957***	***12497***

Table II.6 Distribution of MSW-treatment/disposal costs (million €/year) over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the AP-2010 (without prevention) scenario

Country	*Prevention*	*Treatment*/disposal *methods* Composting	Recycling	Incineration WTE	Incineration no WTE	Landfill Direct	Landfill Indirect	***Total*** **Exclusive Indirect Landfill**	**Inclusive Indirect Landfill**
Austria		100	39	93	0	54	18	**287**	**304**
Belgium		142	27	95	0	32	12	**297**	**310**
Denmark		95	18	99	0	13	16	**224**	**241**
Finland		66	15	75	0	10	12	**166**	**178**
France		438	252	883	0	413	171	**1987**	**2158**
Germany		1175	372	1073	0	594	201	**3215**	**3415**
Greece		181	34	0	0	91	0	**307**	**307**
Ireland		82	21	0	0	54	0	**157**	**157**
Italy		621	191	81	0	609	15	**1502**	**1517**
Luxembourg		8	3	7	0	1	1	**20**	**21**
Netherlands		280	63	178	0	90	30	**611**	**641**
Portugal		126	29	0	0	110	0	**265**	**265**
Spain		512	122	36	0	276	5	**946**	**951**
Sweden		126	25	141	0	18	23	**310**	**332**
United Kingdom		562	231	169	0	686	35	**1649**	**1684**
EU-15		**4515**	**1445**	**2931**	**0**	**3052**	**540**	***11943***	***12483***

1.8 Annex III. Distribution of the specific MSW-treatment/disposal costs over treatment/disposal methods[5]

In table III.1 to III.6, the distribution of MSW-treatment/disposal costs over the five treatment methods is presented for the EU-15 countries for the following scenario's:

- Table III.1: BL-1993 scenario;
- Table III.2: BL-2010 scenario;
- Table III.3: TD-2010a scenario (maximal Incineration WTE);
- Table III.4: TD-2010b scenario (maximal Composting and Recycling);
- Table III.5: AP-2010 scenario (with prevention);
- Table III.6: AP-2010 scenario (without prevention).

Table III.1 Distribution of the specific MSW-treatment/disposal costs over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the BL-1993 scenario

Country	*Treatment*/disposal *methods*						***Total***	
	Composting	Recycling	Incineration		Landfill		**Exclusive Indirect Landfill**	**Inclusive Indirect Landfill**
			WTE	no WTE	Direct	Indirect		
	(€/t)	(€/t)	(€/t)	(€/t)	(€/t)	(€/t)	**(€/t)**	**(€/t)**
Austria	83	6	106		56	56	**61**	**60**
Belgium	74	-5	98	119	49	49	**79**	**76**
Denmark	77	-5	101		51	51	**68**	**66**
Finland	81	-4	105		55	55	**71**	**70**
France	79	-5	103	124	53	53	**80**	**77**
Germany	76	3	100		51	51	**56**	**55**
Greece		-4			55		**51**	**51**
Ireland		-2			56		**55**	**55**
Italy		-4		125	54	54	**56**	**56**
Luxembourg	79	21	103		53	53	**68**	**67**
Netherlands	76	-5	100	121	50	50	**59**	**59**
Portugal	87	-3			60		**62**	**62**
Spain	79	-4	102	123	53	53	**58**	**58**
Sweden	77	-5	101		51	51	**68**	**67**
United Kingdom		-5	100	121	50	50	**54**	**54**
EU-15	**78**	**0**	**101**	**123**	**53**	**52**	***62***	***61***

[5] For individual member states the baseline projection concerning composting for 2010 already underestimates the state of the art for the year 2000 in some cases. This is due to the methodology applied which extrapolates from the Cooper & Lybrand data. See section 2.3 Major uncertainties. This will not change the main conclusion that there is a huge potential for composting in the EU.

Table III.2 Distribution of the specific MSW-treatment/disposal costs over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the BL-2010 scenario

Country	*Treatment*/disposal *methods*						***Total***	
	Composting	Recycling	Incineration		Landfill		**Exclusive**	**Inclusive**
			WTE	no WTE	Direct	Indirect	**Indirect Landfill**	**Indirect Landfill**
	(€/t)	(€/t)	(€/t)	(€/t)	(€/t)	(€/t)	**(€/t)**	**(€/t)**
Austria	81	8	105		55	55	**59**	**59**
Belgium	74	1	98	119	49	49	**71**	**69**
Denmark	76	-3	100		51	51	**66**	**65**
Finland	80	-2	103		54	54	**69**	**68**
France	78	7	102	123	52	52	**70**	**69**
Germany	76	5	100		50	50	**54**	**54**
Greece		5			53		**47**	**47**
Ireland		14			55		**49**	**49**
Italy		5		124	53	53	**49**	**49**
Luxembourg	78	21	102		52	52	**66**	**65**
Netherlands	75	-1	100	120	50	50	**58**	**57**
Portugal	84	10			58		**55**	**55**
Spain	78	9	101	122	52	52	**50**	**50**
Sweden	77	-3	100		51	51	**67**	**65**
United Kingdom		2	100	120	50	50	**46**	**46**
EU-15	**77**	**5**	**100**	**122**	**52**	**51**	***56***	***55***

Table III.3 Distribution of the specific MSW-treatment/disposal cost over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the TD-2010a scenario (maximal Incineration WTE)

Country	*Treatment*/disposal *methods*						***Total***	
	Composting	Recycling	Incineration		Landfill		**Exclusive**	**Inclusive**
			WTE	no WTE	Direct	Indirect	**Indirect Landfill**	**Indirect Landfill**
	(€/t)	(€/t)	(€/t)	(€/t)	(€/t)	(€/t)	**(€/t)**	**(€/t)**
Austria	81	8	105			55	**79**	**75**
Belgium	74	1	98			49	**82**	**78**
Denmark	76	-3	100			51	**76**	**73**
Finland	80	-2	103			54	**78**	**76**
France	78	7	102			52	**84**	**78**
Germany	76	5	100			50	**75**	**71**
Greece		5	103			53	**90**	**86**
Ireland		14	104			55	**93**	**87**
Italy		5	103			53	**87**	**82**
Luxembourg	78	21	102			52	**78**	**75**
Netherlands	75	-1	100			50	**77**	**73**
Portugal	84	10	108			58	**93**	**88**
Spain	78	9	101			52	**85**	**81**
Sweden	77	-3	100			51	**76**	**73**
United Kingdom		2	100			50	**80**	**75**
EU-15	**77**	**5**	**101**			**51**	***81***	***76***

Table III.4 Distribution of the specific MSW-treatment/disposal costs over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the TD-2010b scenario (maximal Composting and Recycling)

Country	*Treatment*/disposal *methods*						***Total***	
	Composting	Recycling	Incineration		Landfill		**Exclusive**	**Inclusive**
			WTE	no WTE	Direct	Indirect	**Indirect Landfill**	**Indirect Landfill**
	(€/t)	(€/t)	(€/t)	(€/t)	(€/t)	(€/t)	**(€/t)**	**(€/t)**
Austria	81	89	105		55	55	**85**	**83**
Belgium	74	70	98	119	49	49	**77**	**76**
Denmark	76	73	100		51	51	**79**	**77**
Finland	80	81	103		54	54	**84**	**82**
France	78	82	102	123	52	52	**84**	**81**
Germany	76	77	100		50	50	**76**	**75**
Greece	79	85	103		53		**80**	**80**
Ireland	81	93	104		55		**81**	**81**
Italy	79	82		124	53	53	**78**	**78**
Luxembourg	78	77	102		52	52	**81**	**79**
Netherlands	75	75	100	120	50	50	**76**	**75**
Portugal	84	95	108		58		**82**	**82**
Spain	78	82	101	122	52	52	**79**	**78**
Sweden	77	74	100		51	51	**79**	**77**
United Kingdom	75	72	100	120	50	50	**71**	**71**
EU-15	**77**	**78**	**101**	**122**	**52**	**51**	***78***	***77***

Table III.5 Distribution of the specific MSW-treatment/disposal costs over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the AP-2010 (with prevention) scenario

Country	*Prevention*	*Treatment*/disposal *methods*						***Total***	
		Composting	Recycling	Incineration		Landfill		**Exclusive**	**Inclusive**
				WTE	no WTE	Direct	Indirect	**Indirect Landfill**	**Indirect Landfill**
	(€/t)	(€/t)	(€/t)	(€/t)	(€/t)	(€/t)	(€/t)	**(€/t)**	**(€/t)**
Austria	35	81	23	105		55	55	**62**	**61**
Belgium	26	74	14	98		49	49	**55**	**55**
Denmark	24	76	14	100		51	51	**61**	**60**
Finland	24	80	17	103		54	54	**64**	**64**
France	37	78	20	102		52	52	**59**	**58**
Germany	35	76	18	100		50	50	**56**	**56**
Greece	40	79	22			53		**56**	**56**
Ireland	57	81	28			55		**59**	**59**
Italy	28	79	18	103		53	53	**51**	**51**
Luxembourg	24	78	26	102		52	52	**64**	**64**
Netherlands	31	75	17	100		50	50	**56**	**56**
Portugal	40	84	24			58		**59**	**59**
Spain	43	78	21	101		52	52	**54**	**54**
Sweden	24	77	14	100		51	51	**62**	**61**
United Kingdom	20	75	14	100		50	50	**43**	**43**
EU-15	**31**	**77**	**18**	**101**		**52**	**51**	***54***	***54***

Table III.6 Distribution of the specific MSW-treatment/disposal costs over the treatment/disposal methods Composting, Recycling, Incineration WTE, Incineration, direct Landfill and indirect Landfill for the EU-15 countries in the AP-2010 (without prevention) scenario

Country	*Prevention*	*Treatment*/disposal *methods*						***Total***	
		Composting	Recycling	Incineration		Landfill		**Exclusive Indirect Landfill**	**Inclusive Indirect Landfill**
				WTE	no WTE	Direct	Indirect		
	(€/t)	(€/t)	(€/t)	(€/t)	(€/t)	(€/t)	(€/t)	**(€/t)**	**(€/t)**
Austria		81	23	105		55	55	**60**	**59**
Belgium		74	14	98		49	49	**54**	**53**
Denmark		76	14	100		51	51	**59**	**59**
Finland		80	17	103		54	54	**63**	**62**
France		78	20	102		52	52	**57**	**56**
Germany		76	18	100		50	50	**55**	**54**
Greece		79	22			53		**55**	**55**
Ireland		81	28			55		**57**	**57**
Italy		79	18	103		53	53	**49**	**49**
Luxembourg		78	26	102		52	52	**63**	**62**
Netherlands		75	16	100		50	50	**55**	**55**
Portugal		84	24			58		**58**	**58**
Spain		78	21	101		52	52	**52**	**52**
Sweden		77	14	100		51	51	**60**	**59**
United Kingdom		75	14	100		50	50	**42**	**42**
EU-15		**77**	**18**	**101**		**52**	**51**	***52***	***52***

1.9 Annex IV. Assumptions for benefit calculations

Unit damage values for a tonne of waste going to different treatment routes:

Assumptions

Unit damage values are drawn from CEC (1996). In this analysis, benefit estimates of the different scenarios are estimated for 2010, thus, unit damage values associated with the 'future MSW configuration under the future configuration Technology scenario' are used.

These values include all the impacts associated with emissions to air and the risk of damage to health from the treatment/disposal of MSW, such as:

- environmental costs associated with the collection and transport of waste;
- environmental costs associated with energy use during the MSW management;
- environmental costs and benefits associated with the MSW process;
- environmental costs associated with the manufacture of bags / bins to collect MSW;
- environmental costs associated with road accidents during the transport of MSW;

Other factors taken into consideration include:

- avoided costs of avoided virgin material production (due to recycling)
- avoided costs of waste treatment/disposal due to prevention
- avoided costs of avoided virgin material production (due to prevention)

Various impacts, for example on water (i.e.leachate) and amenity are not included due to the absence of suitable data. Landfill and incineration facilities, especially when located close to population centres, can cause serious disamenity. The main impacts are visual disamenity, noise, smell and fear of health effects. WTP valuations of such effects have been undertaken in the US for landfill and do show considerable disamenity. For example, a number of hedonic property price studies show that house prices fall depending on their proximity to the landfill site up to an outer limit of 4 miles. However, to include a Europe wide disamenity valuation would be extremely complex and would require detailed information on the distribution of landfill sites and housing / population concentrations (refer to Annex at end of this chapter).

The assumptions behind these values include:

- co-collection of mixed refuse and recyclable and organic materials (using blue box) and
- 50% of organic waste is collected at kerbside and 50% is taken by households to civic composting site
- all incinerators comply with the EC Incineration Directive, which leads to an underestimate of environmental damages from incineration.
- Leachate collection efficiency is assumed to 70% for landfill sites. No economic value is attached to leachate.

For further details of the assumptions refer to CEC (1996).

Modifications to the original unit damage values

- *Unit damage value for a tonne of waste to incineration*: these values are adjusted to assume no energy displacement from incineration. This is achieved by adding back the energy displacement credits assumed within the original unit values.

Unit damage value for a tonne of waste to landfill: An adjustment for the recently adopted EC Directive on the landfill of waste (i.e. due to reduced bio-gas production, energy displacement credited to landfill is reduced by 75%) is made in the following manner. The net environmental costs associated with landfill include the displacement of average EU electricity with an energy recovery efficiency of 30% for electricity. Assuming full implementation of the Directive, in 2010, the level of biodegradable waste going to landfills must be reduced to 25% of the total amount (by weight) of biodegradable municipal waste produced in 1993 (Article 5 Directive on the landfill of waste). Since landfill gas is only produced by the biodegradable fraction of MSW (i.e. organic, paper and textile waste), it follows that less landfill gas will be generated from landfills in 2010. Assuming landfill gas is collected and used to produce energy (see Annex 1 Directive on the landfill of waste) there will be a corresponding reduction in energy recovery. In 1993, we assume 250 N m^3 landfill gas per tonne of biodegradable waste arises. The Directive suggests total landfill gas generated will fall to 25% of 1993 levels by 2010. By implication this leads to a corresponding reduction in the benefits of displaced energy in 2010 for the AP scenarios. This adjustment makes no significant difference to the results largely because the amount of electricity being displaced from landfill is very small. The biodegradable waste will be redirected to composting and recycling management options. Due to the absence of research into how the increased volume of waste directed to composting and recycling will change the environmental costs associated with these treatment options, this study assumes the unit net environmental costs of each are held constant across the scenarios.

Prevented waste adjustment: the AP (with prevention) scenario has less total waste arisings than the other scenarios due to the prevention of a certain tonnage of waste. The benefits of prevented waste are defined as the sum of (i) avoided environmental costs of virgin material production, and (ii) avoided environmental costs of treatment/disposal.

The original unit damage value for recycling contains both the environmental costs of recycling processing and the avoided environmental costs of virgin material production. In order to estimate the avoided environmental costs of virgin material production add back the environmental cost of processing for recycling (assumed to be € 100 per tonne waste). This gives the avoided environmental cost of virgin material production as € -280 per tonne

This value of avoided virgin material production (€ -280 per tonne) is assumed to be valid for all the waste treatment options. The net unit damages for waste *avoided* for each treatment/disposal option will be made up of this value, plus the avoided unit costs of waste treatment/disposal.

Both sets of net unit damage values (waste disposed by each option, and waste avoided) for the different treatment/disposal options are given in Table A.

<u>*Adjustments to obtain 2010 values*</u>

- EU 15 unit damage values for different waste treatment/disposal options are an average of four European countries: Denmark, France, Spain, UK
- 1993 prices are adjusted to 1997 prices using the deflator 15.3%
- Unit damage values are then adjusted for rising relative environmental price due to income change, i.e. 0.5% p.a.

Table A: Net unit environmental costs (€ per tonne) associated with different treatment/disposal options for MSW for EU15.

Net unit damage	*Compost*	*Recycling*	*Incineration WTE 'old coal'*	*Incineration WTE 'EU'*	*Incineration*	*Landfill*
Waste arising	20.3	-185.0	-21.5	18.0	30.0	9.5
Waste prevention	-300	-380	-258	-298	-310	-289

Note: negative values indicate a net unit environmental benefit

1.10 Benefit assessment

1.10.1 Public opinion

Public opinion from a summary of surveys, such as the ones carried out in Denmark in 1995 and in the UK by the Department of the Environment in 1993, ranks waste management ninth out of the eleven environmental problems. Waste management is consistently ranked last in the Eurobarometer, although it is considered a top priority (rank 3) by public opinion in Ireland.

1.10.2 Expert opinion

In GEP et al (1997), waste management is the main issue within a very broad category of problems, which include industrial waste management together with nuclear risk. The general category is ranked sixth.

1.10.3 Benefit estimation

Table 2.1 gives a summary of the benefit estimates of the different scenarios over baseline. The results relate to 2010 only, i.e. the benefit of the TD or AP scenario over Baseline in 2010.

Table 2.1 Summary of benefit of TD and AP scenarios in 2010: € billion

Scenario variant	€ billion
TD maximum incineration	-2.8
TD maximum composting and recycling	10.3
AP with source reduction of waste	8.7
APwithout source reduction of waste	7.2

The benefit estimates may be biased downwards due to:

- assumption that all incinerators comply to EC Directive throughout the whole period 1993-2010;
- exclusion of impacts to water and disamenity for all MSW treatment options, and
- exclusion of energy displacement credits due to incineration of waste.

Suitable indicators and valuation estimates for future research in this area are as follows:

- Volumes of waste per € of GNP
- Volumes of hazardous waste per capita

Methodology

The approach adopted to value the environmental costs of MSW treatment requires three main estimates:

- growth in MSW from the base year 1993[6] to 2010 in all scenarios
- percentage of MSW going to each disposal method
- monetary valuations for the environmental impacts of each disposal method

MSW arisings and the different disposal options

Table 2.2 gives the total waste arisings in the different scenarios. Waste arisings are held constant across the Baseline, TD (max incin), TD (max comp&recy) and AP (without source reduction) scenarios. Waste arisings fall in the AP (with source reduction of waste) scenario only.

Table 2.2 Total European Waste Arising in 1993 and 2010		
Scenario	Total Waste Arising K tonnes per annum	
	1993	2010
Baseline, TD (max incin), TD (max comp&recy), AP (w/o prev)	185,711	228,372
AP (w prev)	185,711	221,595

Note: totals exluded landfill of incineration ashes (see *Table 2.3* for details)

Table 2.3 gives the distribution of waste to the different disposal routes, i.e. composting, recycling, incineration with WTE, incineration and landfill. The total waste arisings differ across the scenarios, due to the level of incineration in each scenario. For example, TD (max incin) generates the highest level of incineration ashes compared to all other scenarios.

Table 2.3 MSW disposal distribution for the TD and AP scenarios								
Scen	Comp	Recycle	$Incin_{WTE}$	Incin	Landfill	Landfill of Incin ashes	Total waste	Total waste incl. LF of incin ashes
1993	10328	19616	27432	16034	112302	11230	185711	196942
BL2010	12525	44338	31996	15381	124133	12069	228373	240442
TD_{incin}	12525	44338	171510	0	0	42728	228373	271101
TD_{C+R}	62789	98114	19021	11212	37236	8049	228373	236422
$AP_{w/o\ P}$	58513	81765	29098	0	58997	10538	228373	238911
$AP_{with\ P}$	57234	76681	28957	0	58723	10538	221595	232133

Valuing environmental impacts from different waste disposal options

[6] Waste management differs from all other environmental issues, because the base year is taken as 1993. Data prior to this date are very unreliable.

The monetary valuations are based on the environmental cost of one tonne of MSW going to various MSW disposal methods estimated in EC (1996). The unit values are based on the average of four EU countries (Denmark, Spain, France and the UK). Where each country has a set of net environmental values, which are dependent on various country specific characteristics. The valuation techniques were based on a combination of life cycle analysis and economic valuation taken from various previous studies. They are adapted for each EU15 country using the 'benefits transfer' approach. For each country environmental impact monetary values are given for the following five MSW management options

- Landfill;
- Incineration (not with Waste to Energy) (WTE);
- Incineration (with WTE);
- Composting, and
- Recycling.

The benefits associated with disposing waste via incineration with WTE facilities are estimated according to different assumptions about whether power generation technology is displaced by the energy produced from the incinerators or not. Two estimates are given: (i) *excludes* the benefits of energy displacement, (ii) assumes EU average energy displacement.

The unit damage values for one tonne of waste going to the different waste disposal options used in this analysis are presented in *Table 2.4*. *Table 2.4* also reports the unit benefit value for one tonne of waste prevented from going to the different disposal routes.

Details of the assumptions and modifications made to the unit damage values and unit benefit values for waste prevented, are given at the end of this section.

Table 2.4	Net unit environmental damage associated with different disposal options for EU15: € / tonne of MSW				
Net unit damage	Compost	Recycling	Incineration WTE 'EU'	Incineration	Landfill
Waste arising	20.3	-185.0	18.0	30.0	9.5
Waste prevented	-300	-380	-298	-310	-289

Note: negative values indicate a net unit environmental benefit

Summary of scenario benefits

The monetised environmental costs for each scenario are reported in *Table 2.5*.

Table 2.5	Total environmental damage in 2010: € billion (1997 prices)				
EU-15	BL	TD (max Incin)	TD (max C&R)	AP-with source reduction of waste	AP-w/o source reduction of waste
No energy displacement	-5.25	-2.43	-15.50	-13.90	-12.40
EU average energy displacement	-5.63	-4.43	-15.80	-14.30	-12.70

Note: waste arisings data include landfill of incineration ashes

The results show large environmental benefits in the year 2010 in EU15 for TD (max compost and recycling) and AP scenarios as indicated by the large negative costs. The main source of these large environmental benefits is the displaced environmental impact of virgin material manufacture by recycling. By comparison, the TD (max incineration) scenario yields less environmental benefits than the baseline.

This is because almost five times as much waste is sent to incineration in the TD (max incin) scenario compared to the Baseline in 2010 (i.e. 63% for TD(max incin) and 13% for Baseline), even though the Baseline scenario has a higher proportion of waste going to landfill than the TD (max incin) scenario (i.e. 57% compared to 16%) the unit damage price for a tonne of waste to incineration is almost double that of waste to landfill (i.e. € 18/tMSW for incineration compared to € 9.5/tMSW for landfill). Overall, the environmental damage due to the TD (max incin) scenario is greater than the Baseline in 2010.

The benefits of each scenario, otherwise described as the avoided environmental damage of moving from the Baseline to the TD and AP scenarios respectively, are given in monetary form in 2*.6*.

Table 2.6 Environmental benefits in 2010: € billion

EU-12	TD max incin	TD comp&recy	AP with source reduction of waste	AP without source reduction of waste
No energy displacement	-2.83	10.3	8.69	7.15

Note: negative benefit values indicate environmental cost. Benefit estimates assume 'no energy displacement'

The main findings of the analysis show there are clear advantages to be had from moving to the TD (comp&recy) and AP policy scenarios. This is due to the increased percentage of waste recycled and the associated displaced environmental impact of virgin material manufacture. Whilst it would be an environmental loss to move from the baseline to the TD (max incin) scenario. This is explained above, i.e. even though waste arisings are the same as in the Baseline scenario and waste sent to composting and recycling are the same, the percentage of waste going to incinerators with WTE is more than five times greater in the TD (max incin) and this is valued at double the unit damage value for landfill.

The AP (with source reduction of waste) benefit estimate includes the benefits of avoided waste disposal and avoided virgin materials production. As would be expected the benefits are greater for AP (with source reduction of waste) than for AP (without source reduction of waste). But the benefits for AP (with source reduction of waste) are less than for the TD (comp&recy) scenarios. This is explained by the higher proportion of waste sent to incineration and landfill and less waste going to recycling in the AP (with source reduction of waste) scenario. This last difference is important because fewer tonnes of waste go to the disposal methods which give environmental benefits (rather than costs) per tonne, i.e. recycling.

Sensitivity Analysis

Table 2.7 below shows the effects on the main results of changing some key assumptions of the analysis.

Table 2.7	Key assumptions and the estimated results of changing these assumptions		
Current Assumption	Current value € 10^9	Revised assumption	Revised value € 10^9
Includes landfill of incin ashes No energy displacement from incin: *(Benefit value in 2010 Not discounted)* TD (max incin) TD (comp&recy) AP waste reduction AP w/o waste reduction	 -2.8 10.3 8.7 7.2	Excludes landfill of incin ashes. No energy displacement from incin. *(Benefit value in 2010, not discounted)* TD (max incin) TD (comp&recy) AP with waste reduction AP w/o waste reduction	 -2.5 10.2 8.7 7.1
No energy displacement Inc landfill of incin ashes *(Benefit value in 2010 Not discounted)* TD (max incin) TD (comp&recy) AP waste reduction AP w/o waste reduction	 -2.8 10.3 8.7 7.2	EU average energy displacement Inc landfill of incin ashes *(Benefit value in 2010 Not discounted)* TD (max incin) TD (comp&recy) AP waste reduction AP w/o waste reduction	 -1.2 10.1 8.6 7.1
No energy displacement Inc landfill of incin ashes *(Benefit value in 2010 Not discounted)* TD (max incin) TD (comp&recy) AP waste reduction AP w/o waste reduction	 -2.8 10.3 8.7 7.2	Old coal energy displacement Inc landfill of incin ashes *(Benefit value in 2010 Not discounted)* TD (max incin) TD (comp&recy) AP waste reduction AP w/o waste reduction	 -4.34 -9.61 -8.52 -7.00

Note: unless otherwise indicated all results assume no energy displacement and include the landfill of incineration ashes.

Disamenity

The benefit estimates of moving from the Baseline to the TD and AP scenarios are based upon unit damage values per tonne of waste going to different waste management options. These values are derived from an LCA analysis (EC 1997). LCA procedures do not typically include site disamenity associated with waste disposal options. Yet it is recognised that landfill sites and incinerators are the subject to often, sustained public opposition. It is not therefore rational from a social standpoint to base policy or technology choices on typical life cycle impacts alone.

The disamenity impacts associated with landfill sites, incinerators, municipal compost sites and recycling sites are excluded from the analysis in this study on the basis that at the time of writing there are very few reliable studies available in Europe.

However, a recent study by Garrod and Willis (1997) suggests that WTP to reduce amenity loss is relatively low. They examine the impacts that a well-established UK landfill site has on the people who live around it and they estimate the magnitude of these impacts in monetary terms. The findings of the study are that many residents experience minimal impacts having learnt to live with the landfill site and so the willingness-to-pay for reducing impacts is relatively low. Admittedly these figures do not reveal the levels of welfare loss associated with the establishment of the facility. But the authors suggest this figure may also be low given that residents were at the time used to the disamenity associated with the site in its previous state as a quarry.

The method used to estimate WTP to avoid 'LULUs' - locally undesirable land uses that is most suitable to the practice of benefits transfer is the hedonic property price technique. Brisson and Pearce (1995) survey the North American hedonic price literature to 1995. Based on a meta-analysis of the HPP studies considered, Brisson and Pearce (1995) suggest a linear meta-function: HP = 12.8 - 3.76D

Where HP is the percentage change in house price and D is the distance in miles from the LULU. Thus, numerical changes would be:

Distance from LULU (miles)	% Depreciation in house price
0	12.8
1	9.0
2	5.2
3	1.4
3.4	0

Based on the Brission and Pearce (1995) meta-analyis, the procedure for calculating disamenity losses can be stated as: $N_i.(12.8 - 3.76\ D_i).HP_i$

Where N_i is the number of houses in district i; D is the distance of the relevant district from the site, in miles; and HP_i is the prevailing average house price in district i.

To include a Europe wide disamenity valuation would rely on literature outside EU15. It would be extremely complex and would require detailed information on the distribution of LULUs and housing / population concentrations. Thus disamenity loss is excluded from this study.

Unit damage values: assumptions

Unit damage values are drawn from CEC (1996). In the analysis of waste management, benefit estimates of the different scenarios are estimated for 2010, thus, unit damage values associated with the 'future MSW configuration under the future configuration Technology scenario' are used.

These values include all the impacts associated with emissions to air and the risk of damage to health from the disposal of MSW, such as:

- environmental costs associated with the collection and transport of waste;
- environmental costs associated with energy use during the MSW management;
- environmental costs and benefits associated with the MSW process;
- environmental costs associated with the manufacture of bags / bins to collect MSW, and
- environmental costs associated with road accidents during the transport of MSW.

Other factors taken into consideration include:

- avoided costs of avoided virgin material production (due to recycling);
- avoided costs of waste disposal due to prevention, and
- avoided costs of avoided virgin material production (due to source reduction of waste).

Various impacts, for example on water (i.e.leachate) and amenity are not included due to the absence of suitable data. Landfill and incineration facilities, especially when located close to population centres, can cause serious disamenity. The main impacts are visual disamenity, noise, smell and fear of health effects. WTP valuations of such effects have been undertaken in the US for landfill and do show considerable disamenity. For example, a number of hedonic property price studies show that house prices fall depending on their proximity to the landfill site up to an outer limit of 4 miles. However, to include a Europe wide disamenity valuation would be extremely complex and would require detailed information on the distribution of landfill sites and housing / population concentrations (refer to Annex at end of this chapter).

The assumptions behind these values include:

- co-collection of mixed refuse and recyclable and organic materials (using blue box) and
- 50% of organic waste is collected at kerbside and 50% is taken by households to civic composting site
- all incinerators comply with the EC Incineration Directive, which leads to an underestimate of environmental damages from incineration.
- Leachate collection efficiency is assumed to 70% for landfill sites. No economic value is attached to leachate.

For further details of the assumptions refer to CEC (1996).

Modifications to the original unit damage values

- *Unit damage value for a tonne of waste to incineration*: these values are adjusted to assume no energy displacement from incineration. This is achieved by adding back the energy displacement credits assumed within the original unit values.

Unit damage value for a tonne of waste to landfill: An adjustment for the recently adopted EC Directive on the landfill of waste (i.e. due to reduced bio-gas production, energy displacement credited to landfill is reduced by 75%) is made in the following manner. The net environmental costs associated with landfill include the displacement of average EU electricity with an energy recovery efficiency of 30% for electricity. Assuming full implementation of the Directive, in 2010, the level of biodegradable waste going to landfills must be reduced to 25% of the total amount (by weight) of biodegradable municipal waste produced in 1993 (Article 5 Directive on the landfill of waste). Since landfill gas is only produced by the biodegradable fraction of MSW (i.e. organic, paper and textile waste), it follows that less landfill gas will be generated from landfills in 2010. Assuming landfill gas is collected and used to produce energy (see Annex 1 Directive on the landfill of waste) there will be a corresponding reduction in energy recovery. In 1993, we assume 250 N m^3 landfill gas per tonne of biodegradable waste arises. The Directive suggests total landfill gas generated will fall to 25% of 1993 levels by 2010. By implication this leads to a corresponding reduction in the benefits of displaced energy in 2010 for the AP scenarios. This adjustment makes no significant difference to the results largely because the amount of electricity being displaced from landfill is very small. The biodegradable waste will be redirected to composting and recycling management options. Due to the absence of research into how the increased volume of waste directed to composting and recycling will change the environmental costs associated with these disposal options, this study assumes the unit net environmental costs of each are held constant across the scenarios.

Prevented waste adjustment: the AP (with source reduction of waste) scenario has less total waste arisings than the other scenarios due to the prevention of a certain tonnage of waste. The benefits of prevented waste are defined as the sum of (i) avoided environmental costs of virgin material production, and (ii) avoided environmental costs of disposal.

The original unit damage value for recycling contains both the environmental costs of recycling processing and the avoided environmental costs of virgin material production. In order to estimate the avoided environmental costs of virgin material production add back the environmental cost of processing for recycling (assumed to be € 100 / tonne waste). This gives the avoided environmental cost of virgin material production as € -280 / tonne

This value of avoided virgin material production (-280 €/tonne) is assumed to be valid for all the waste disposal options. The net unit damages for waste *avoided* for each disposal option will be made up of this value, plus the avoided unit costs of waste disposal.

Both sets of net unit damage values (waste disposed by each option, and waste avoided) for the different disposal options are given in *Table 2.8*.

Adjustments to obtain 2010 values

- EU 15 unit damage values for different waste disposal options are an average of four European countries: Denmark, France, Spain, UK;
- 1993 prices are adjusted to 1997 prices using the deflator 15.3%, and
- Unit damage values are then adjusted for rising relative environmental price due to income change, i.e. 0.5% p.a.

Table 2.8	Net unit environmental damage associated with different disposal options for EU15: € / tMSW					
Net unit damage	Compost	Recycling	Incineration WTE 'old coal'	Incineration WTE 'EU'	Incineration	Landfill
Waste arising	20.3	-185.0	-21.5	18.0	30.0	9.5
Waste prevent	-300	-380	-258	-298	-310	-289

Note: negative values indicate a net unit environmental benefit.

2. Policy package

2.1.1 Recommended policy initiatives

Domestic Waste

Virgin materials tax

It is an interesting reflection on most waste management policy that it is directed at waste once it has been generated, rather than at source reduction per se. This runs counter to the waste hierarchy as espoused in most countries and particularly by the European Commission. Innovative policy on waste should therefore be directed at source reduction, i.e. at preventing waste from arising in the first place. This suggests a focus on making waste generation expensive. While, in principle, this is achieved by taxes on emissions or products, there are strong arguments in favour of material or input charges and taxes. Particularly relevant are the monitoring and administrative costs of charges aimed at emissions to the environment. Inputs tend to be more easily measurable. In some contexts, e.g. packaging, environmental impacts tend to be associated with the material input rather than the specific product or emission. Virgin materials taxes should encourage source reduction and the use of secondary materials (recycling). Finally, waste taxes have an in-built incentive for evasion through, e.g. fly tipping (which has been one of the results of the UK landfill tax). Hence materials taxes have several attractions.

Despite these attractions, there appear to be few examples of virgin material taxes in the EU. The Italian scheme, imposing a 10% recycling charge on polyethylene for plastic bags to finance recovery and recycling was dropped in 1997 following pressure from the European Commission and industry suggesting it was a trade barrier. Denmark, introduced a tax on plastic bags in 1994, based on the weight of the bag rather than per piece. And Ireland aims to tax plastic carrier bags at € 0.04 per bag by December 1999 (see Action 8.2 product tax).

Bruvoll (1998) simulates a hypothetical tax on virgin paper and plastics for Norway. The tax is set at 15% of the price of virgin materials, although Bruvoll suggests that disposal and environmental costs associated with these materials amount to 50-480% of virgin prices. Using a general equilibrium model she shows that packaging waste in Norway would decline by 8.5% over a 10 year period, use of paper and plastics would decline by 11% over a 30 year period. There would also be a slight reduction in GDP, but Norwegian payroll taxes could be reduced by 3%. Using unit shadow prices for environmental impacts, Bruvoll (1998) estimates that damages in 2030 would be reduced by 320-3300 million NOK (€ 40 - 412 million).

Bruvoll's analysis for Norway suggests that serious consideration should be given to a virgin materials tax as a substitute for landfill and other disposal taxes. A crude elasticity estimate suggests that a 1% charge on virgin materials would lead to a 0.5% (i.e. 8.5/15,) change in packaging waste over 10 years, and a 0.25% change in the use of the taxed material over the same period (i.e. 11/(15*3)). Thus, the elasteicities for overall packaging waste and for paper and plastics in specific are -0.5 and -0.25 respectively.

Product Tax

In principle it is possible to devise product taxes so that they reflect the costs of waste disposal. The following formula for product p, can be used:

$$T_p = W_p (1-r_p).C$$

Where T is the tax rate per unit of weight (or volume) of waste, r is the recycling rate, W is the weight of waste, and C is the marginal social cost of disposal. Such a tax varies directly with the amount of waste (e.g. the weight of a beverage container), negatively with the rate of recycling (r) and positively with the costs of disposal. The tax is most easily interpreted in the context of packaging. Provided the weight of the packaging is known and there is some estimate of current recycling rates, then C is easily estimated as the disposal cost. Data limitations are not therefore serious. (weight can also be standardised across the size or weight of the product (e.g. weight of container per litre of beverage).

The product tax is also easily converted to a virgin materials tax as

$$T_v = W_v (1-r_v).C.$$

Neither product taxes of this form nor virgin material taxes exist in the EU. Interestingly, a product tax on packaging that resembles the formula above does exist in Hungary (Lehoczki, 1999). The packaging charge is differentiated according to environmental impact (which would be included in C above), the costs of treating waste (also in C) and the ability of the economic sector to bear the burdens of the charge. There is an exemption from the charge if there is significant recycling (see r above). The tax is in fact lowest on glass and paper and highest on plastics and mixed waste. This ranking may have some rationale in the potential for recycling but it is unclear that it is related to disposal costs or externalities in a proportionate manner. While the tax is complex and costly to implement, Lehoczki (1999) suggests that it has been highly effective since it signalled the seriousness with which packaging waste was taken in Hungary, stimulating major companies to take action of their own to recycle and reduce packaging. It is also the case that the packaging charge produced the second highest revenue from product charges in Hungary in 1996.

Recycling credits

The recycling credit is unusual in that it consists of a transfer of funds between different agents in the waste sector. There are no revenues to or expenditures by government. Essentially, those who collect or dispose of waste transfer the cost of avoided disposal to those who engage in incremental recycling. Thus, if a collection or disposal authority would have spent 20 € per tonne disposing of waste, and that tonne is recycled instead of going to disposal, the saved 20 € becomes available as a credit for recyclers. Since the marginal (private) costs of disposal in the UK are high, the credits have the potential to transform the economics of recycling.

Disposal authorities are legally obliged to pay collection authorities (the former tend to be county councils in the UK, while the latter tend to be district or borough councils), but need pay others on a voluntary basis only. Waste collection authorities are similarly not legally obliged to pay NGOs etc for waste they have recycled. Most of the recycling credits have in fact been paid to waste collection authorities, and only limited amounts have been paid to the private sector or NGOs or charities.

The introduction of the recycling credit scheme in the UK has two phases: (i) setting up the operational and administrative arrangements and familiarising the parties involved with their roles and responsibilities, credits valued below long run marginal cost of disposal (ii) the value of the credits move to the full long run marginal cost. The experience in the UK suggests that the first stage is largely complete and due to the initial low level at which the credits during this period no statistically significant effect of the credits on recycling occurred (Pocock and Thomas, 1995). The UK scheme has now entered the second phase and credits were revised so as to reflect the marginal private costs of disposal, substantially raising the credits. It is expected that the level of recycling activity will increase significantly.

While the evidence is limited, our judgement is that recycling credits are a potentially very powerful weapon for increasing the rate of recycling.

Landfill tax

Landfill taxes are in place in several EU countries. Assessing their environmental effectiveness is complex, however. Probably the most detailed estimates for effectiveness come from the analysis for Denmark's waste tax (Skou Anderson (1997). The tax is levied on household and industrial waste going to landfill and incinerator sites. From 1987 to 1992 the tax did not differentiate between incinerators and landfills or between incinerators with and without heat recovery. In 1993 the tax was made higher for landfill than for incinerators and in 1997 it was further differentiated so that the tax was higher for landfill than for incinerators without heat recovery, which was higher than the tax for incineration with heat recovery. The tax change in 1990 amounted to a 225% increase in the tax, and the data for waste deliveries show a 15% reduction in waste delivered to registered sites, suggesting an elasticity of waste reduction of –0.065.

Interestingly, a very low elasticity is also seen in the preliminary work for the UK landfill tax (Coopers and Lybrand, 1993). There it is suggested that an increase in landfill costs of some 33% would result in reduced tonnages to landfill of 5%, giving an implied price elasticity of –0.151. Subsequent evaluations of the UK tax suggest that industry had reduced the amounts it sent to landfill but that there had been no effect on household waste (Morris et al, 1998; HM Customs and Excise, 1998; ECOTEC, 1997, and Coopers and Lybrand, 1997). The lack of any impact on household waste is unsurprising since there is no direct charge on UK households for the landfill tax: it shows up in the overall local authority tax which is charged for all local services. Thus households would not achieve any reduction in their individual tax if they reduced waste generation or increased recycling.

Skou Anderson (1998) notes that some materials recycling was very responsive to the tax, notably garden waste and construction waste. In sectors where recycling was already well established (e.g. paper and glass) the tax had little incremental effect.

The limited information suggests that landfill (and incineration) taxes will achieve little by way of direct reductions in the amount of waste going to landfill, although it needs to be noted that in both the Danish and UK cases, the initial tax levels were substantial, and in both cases significant increments in the tax have been implemented or announced.

Does this mean that landfill taxes are ineffective? The very low price elasticities suggest that the tax *on its own* would be ineffective. But landfill taxes have the capacity to generate considerable revenues simply because landfill is 'pervasive' to most European economies. The UK landfill tax generates some £475 million or € 686 million, which makes it a substantive tax. The UK tax is also revenue neutral in that receipts are hypothecated for two purposes: reductions in the employer-paid labour tax, and certain environmental activities. If full provision were made of the tax credit allowances in the tax, then 20% of revenues would go to environmental schemes and 80% to labour tax reduction. Landfill operators are entitled to claim credit against expenditures on approved environmental schemes provided these do not exceed 20% of total tax liability. In October 1996-October 1997 operators spent £64 million on such schemes and in 1997-98 they spent £76m which is around 80% of the theoretical maximum of £95 million. This suggests that the take up of this form of tax relief is very high. It is not possible to measure the environmental effectiveness of the use of the funds released by tax credits, not least because published accounts are not issued by Entrust, the body responsible for monitoring and checking the schemes that are eligible for use of tax credit expenditures. This is a deficiency of the UK scheme as it stands, but the take up of tax credits does suggest that the potential for high environmental effectiveness is there.

It should be noted that the main purpose of the hypothecated tax revenues in the UK landfill tax is to encourage employment.

A study by CSERGE et al (1993) suggests that 60-70% of the total externality from landfill sites without energy recovery arises from methane. In sites where some of the methane is captured for energy recovery, the net methane release is some 40-50% of the remaining externality. Landfill taxes should therefore reflect the methane damages as a significant proportion of the overall tax.

Collection Fees

European households are typically charged a fixed fee for their waste collection service, irrespective of quantity or composition of the waste they produce. The fixed fee system aims to cover the cost of collection, but it does not encourage households to reduce their waste. Increasingly, municipalities are turning to variable rate charging for domestic waste. Methods for charging vary between simply setting a price for refuse sacks or labels, through to sophisticated weight-based billing systems. Variable collection fees provide major incentives to households to reduce waste as there is a direct financial reward to those households who engage in re-use, waste recycling and composting. In the Netherlands, municipalities that operate a 'pay-per-bag' system report 10-20% less waste per capita than municipalities applying uniform charges, (Henderson, 1996).

A number of weight-based billing systems for household waste collection are in operation in Sweden.

(i) In 1994, Tvååker introduced a fee, set at € 0.14 per kg (1.25kr per kg), although the curb-side collection of paper and glass for recycling is free. Households can take other materials suitable for recycling to one of many nearby recycling centres. Sterner and Bartelings (1999) estimate that the effect of the Tvååker system was a once and for all 29% decrease.

(ii) In 1993, Eda, the initial fee was set at € 0.11 per kg (1kr per kg). Sterner and Bartelings (1999) report a dramatic reduction in annual waste collected. From 553 kg per household in 1993, to 284 kg per household in 1994, i.e. a reduction of 48%. The fee was then raised to € 0.14 per kg, (1.25kr per kg) and the waste disposal figures continued to decline. By 1996, they fell another 18% compared to 1994 levels. Sterner and Bartelings (1999) suggest that if the decrease can be attributed to a rise in tariff from € 0.11 to 0.14 per kg, then a crude price elasticity for waste is high at -0.7.

As the experience in Sweden shows, a weight based fee system can have a substantial negative effect on the levels of waste discarded. The high price elasticity of demand estimated for Eda, represents a rural area with an extremely low population density. The dramatic fall in waste can in part be explained by greater opportunities for composting, waste storage and perhaps local disposal. It is not representative of Europe as a whole. If we assume a system similar to that used in Tvååker, implemented in the EU generates the same impact on waste reduction. This corresponds to a 29% reduction of 186 million tonnes waste (1990 waste arisings, TME 1990), i.e. 54 million tonnes.

The main drawback to variable collection fees is illegal dumping. In the Netherlands, this is not reported as a major problem provided that the price per waste bag does not exceed € 0.9 (NLG 2).
In Eda, Sweden, where household waste is reduced to the low figure of 233 kg / household, local authorities have also not observed any fly tipping. If we assume a bag of waste can weigh between 2-6.kg, a bag of waste in Sweden could cost between € 0.28 - 0.84, i.e. below the estimated threshold for fly-tipping.

Hazardous waste

Disposal reward scheme

It is typically argued that hazardous waste is an environmental problem best dealt with by command and control measures. This is because not only must the total quantities and their environmental toxicity be controlled, but the means of producing and transporting those wastes must also be controlled. Put another way, both the output and the means of producing the output have to be controlled. In contrast, market based approaches cannot provide the certainty that discharge limitation targets will be met, and there is less certainty about compliance (e.g. waste might illegally be tipped). It might also be argued that hazardous waste damage is subject to thresholds, so that most market based approaches (e.g. taxes) risk not achieving disposal levels below the threshold.

In these circumstances, the option of paying for proper disposal is potentially attractive. In this case, owners of such waste would be paid to dispose of the waste to regulated sites. Reward systems differ from the penalties implicit in the polluter pays principle in that the disposer simply has to prove he has done the desirable thing, rather than being charged for doing something undesirable. A variation on this principle is to adopt a tax but to exempt from the tax anyone disposing of waste to regulated sites, but this reintroduces the problem of monitoring disposal. Reward systems have their own problems: rewards must be high enough to ensure that the reward leads to compliance, but not so high that disposers ‘cheat’ by exaggerating waste disposals in order to capture more rewards. Rewards are also, of course, a drain on government finances. Mixing rewards and taxes is achieved with deposit-refund schemes. Here again there are problems since hazardous waste will often take physical forms that make the concept of a deposit difficult to implement and even harder to determine if it is eligible for refunds, e.g. liquid wastes. Additionally, damage might be location-specific, making the concept of a general deposit/refund difficult to implement.

Overall, the hazardous waste problem might be most effectively controlled through a disposal reward system. While this implies a demand on central government resources, society does place a very high premium on the correct disposal of such wastes. Given the problems of ensuring that it is safely disposed of through command and control means and through more conventional market based approaches, reward systems seem worth considering.

2.1.2 Multiple benefits

Policies that reduce the quantity waste going to landfill sites will benefit the issue of climate change, (due to the reduction in methane emissions). The AP scenario assumes a reduction of 65 million tonnes of carbon equivalent, due to the reduction of biodegradable waste to landfill. This is valued at € 440 million, with a range of € 140 - 1020 million, in monetary terms. Other environmental issues that will benefit from waste management policies are water management and soil degradation (i.e. leachate reduction). Whilst, policies that control the level of waste sent to incinerators will benefit the issue of chemical risks.

2.2 Policy assessment

The main policy initiatives are, i) virgin materials tax, product tax, ii) recycling credits, iii) landfill tax, and iv) collection fees.

Causal criterion

Table 3.1 lays out the driving forces behind the waste management problem, the underlying causes of these driving forces are also identified.

Table 3.1	Driving forces and underlying causes of climate change			
	Driving force	Underlying cause		
		MF	IntF	ImpF
D1	Population change			
D2	Growth of paper and board industry due to growing demand for packaging materials			
D3	Inefficient processes, non-optimal use of energy and materials	X		
D4	Presence of hazardous waste in municipal waste reducing recycling possibilities		X	X
D5	Increasing recycling costs and lack of markets for secondary materials	X		
D6	Illegal dumps			X

X = main underlying cause, MF = market failure, IntF = intervention failure, ImpF = implementation failure. Note that for driving forces D1, D2 the main causes are due to growth in population and real income.

Virgin materials tax: these provide incentives for source reduction i.e. at preventing waste from arising in the first place thus. Virgin materials taxes may also encourage the use of secondary materials, (i.e. recycling) thus, underlying causes are addressed

Product tax: effective in encouraging substitution away from product as long as there are substitutes.

Recycling credits provide incentives to redirect waste from other disposal routes to recycling. Both the landfill tax and the recycling credits provide incentives to redirect waste away from landfill sites.

Landfill tax: in general, experience shows that when the landfill tax is set at the level of the externality it does not seem to affect the waste flows into landfill sites. Landfill taxes will only be effective in encouraging waste reduction and recycling if the charge is passed on to the waste generators. Another problem with waste taxes is that they generally have an in-built incentive for evasion through fly tipping.

Collection fees: variable collection fees provide major incentives to households to reduce waste as there is a direct financial reward to those households who engage in re-use, waste recycling and composting, thus underlying causes are addressed. However, such a system may provide incentives for households to manage their waste in other ways, for example, fly tipping, waste incineration at home, etc.

Efficiency criterion

Benefit-cost ratio the AP scenario

B/C ratios are estimated for the TD and AP scenarios. The first set of B/C ratios are found by comparing the benefits of the different waste management scenarios with the direct costs, whilst the second set of B/C ratios are estimated by comparing the benefits with the welfare costs of the different waste management scenarios. The results are given in *Table 3.2*.

Table 3.2 B/C ratios for TD and AP scenarios		
Scenario	B/C ratio Based on welfare costs	B/C ratio Based on direct costs
TD (maximum incineration)	-b	-b
TD (maximum composting and recycling)	3.6	2.1
AP (with source reduction of waste)	-c	-c
AP (without source reduction of waste)	-c	-c

-b = missing ratios due to negative benefits, -c = missing ratios due to negative costs.

B/C ratios are not calculated for waste management Accelerated Policy scenarios, because both the welfare and direct costs are negative. In other words, it is a benefit to move to the AP scenarios. This suggests that the AP scenario targets are economically efficient for waste management.

The Technology Driven scenario with maximum compost and recycling is also justified in economic terms, the ratio of benefits to costs is estimated to be between 2.1 - 3.6, where low/high ratios assume direct costs, welfare costs respectively. However, the Technology Driven scenario with maximum incineration is economically inefficient due to the negative benefit estimates. This implies it is a cost to the environment to move to the TD with maximum incineration scenario, which effectively reduces the B/C ratio to zero.

Benefit assessment of TD and AP scenarios

The benefits of TD and AP scenarios over the baseline in 2010 only, are given in *Table 3.3*.

Table 3.3 Benefits of the TD and AP scenarios in 2010: € billion

Scenario	No energy displacement	EU average energy displacement
TD (maximum incineration)	-2.8[7]	-1.2
TD (maximum composting and recycling)	10.3	10.1
AP (with source reduction of waste)	8.7	8.7
AP (without source reduction of waste)	7.2	7.1

Two values are given. They differ only in their treatment of waste to incineration with WTE facilities. The first set of values exclude all benefits of energy displacement, while the second set of values assume EU average energy displacement. This issue is only of importance for the TD (maximum incineration) scenario, where waste to incinerators with WTE facilities increases from 31,996 k tonnes in the Baseline to 171,510 k tonnes. For the other scenarios this issue is of low importance, mainly because the other scenarios send very little waste to this waste disposal route and the unit damage costs of waste to incinerators with and without WTE differ only slightly[8].

The AP scenario with source reduction of waste benefit estimates are greater than the AP scenario without source reduction of waste because it includes the benefits of avoided waste disposal and the benefits of avoided virgin materials production. Interestingly, the AP scenario with source reduction of waste benefit estimates are less than for the Technology Driven scenario with maximum composting and recycling, estimated to be € 10.3 billion.

This can be explained by the distribution of waste assumed for the different scenarios, where more waste is sent to incineration and less waste is sent to recycling in the AP scenario with source reduction of waste than the Technology Driven scenario with maximum compost and recycling. This means fewer tonnes of waste go to the disposal method which gives environmental benefits (rather than costs) per tonne, i.e. recycling. Moving from the Baseline to the Technology Driven scenario with maximum incineration yields negative benefits at € -2.8 billion, i.e. it is a cost to the environment to move to this scenario. This apparently counter-intuitive result is explained by the distribution of waste over the different disposal routes in the two scenarios. For example, it is assumed that all waste to landfill in the Baseline is re-directed to incineration in the TD scenario with maximum incineration. This means over five times as much waste is incinerated in the TD scenario with maximum incineration, compared to the Baseline. The unit damage value for a tonne of MSW to incineration is almost double the unit damage value of a tonne of MSW to landfill. Thus, the total environmental damage in 2010 for the TD (maximum incineration) scenario is greater than for the Baseline. Thus, moving to the TD (maximum incineration) scenario from the Baseline yields damages (i.e. costs) rather than avoided damages (i.e. benefits).

[7] Negative environmental benefits, imply it is a cost to move to this scenario, B/C ratios become zero.
[8] Incineration with WTE (EU Average energy displacement): € 18 per tonne waste, whilst unit damage cost for incineration without energy displacement: € 30 per tonne waste

2.2.1 Secondary benefits

The AP scenario for waste management generates considerable secondary benefits in terms of reduced greenhouse gas emissions. The reduction of biodegradable waste to landfill will reduce methane emissions from landfill sites, estimated to be approximately 65 million tonnes of CO_2 eq. The secondary benefits to climate change from reduced methane emissions at landfill sites in 2010, are valued at € 440 million, with a range of € 140 - 1020[9] million.

Costs of TD and AP scenario

Table 3.4 provides the direct costs and welfare costs for the different waste management scenarios. Welfare costs are found by assuming that welfare loss is about one third less than the direct costs for the TD and AP scenarios.

Table 3.4	Welfare and direct costs for waste management	
Additional costs (costs AP 2010 - Baseline costs 2010)	Welfare costs € billion	Direct costs € billion
TD (max incineration)	2.9	4.8
TD (max composting and recycling)	2.9	4.8
AP (with source reduction of waste)	-0.48[10]	-0.8
AP (without source reduction of waste)	-0.48	-0.8

Cost-effectiveness

Virgin materials tax / product tax: cost efficient because automatically ensures resources switched at lowest cost. Assuming the virgin materials tax secures the full 6778 ktonne reduction in waste, direct and welfare costs are estimated as negative € 0.8 - 0.48 billion respectively, whilst the benefits of not producing waste are roughly € 2.4 billion. This suggests the virgin materials tax is economically efficient.
Recycling credits: these schemes require the transfer of funds between different agents in the waste sector. There are no revenues to or expenditures by government. This policy option must be cost effective because the only cost is the administrative cost involved.
Landfill tax: likely to be less cost efficient where the environmental costs associated with transport are high. A tax based on volume is best but difficult to administer. Tax based on value is easier to administer, whilst a tax on weight requires banding and weigh-bridges.
Collection fees: ensure households take cost of waste collection into account

Public opinion

Eurobarometer (1995) shows that most Europeans are prepared to change their consumption behaviour as a step to slow down or perhaps even stop the deterioration in the environment as a whole. Although public opinion regarding the issue of waste management is not known with certainty, the results of the Eurobaromter (1995) suggest that the European population may be in favour of measures to reduce waste at source, such as the virgin materials tax. In the UK, the introduction of recycling credits met little public resistance, this is because this measure makes use of savings to local authorities from avoiding waste disposal to, for example, landfill, in order to fund recycling. On the other hand, measures such as collections fees and landfill taxes may meet strong public opposition.

2.2.2 Administrative complexity

Virgin materials tax: It is difficult to determine the degree of administrative complexity associated with virgin material taxes as there are none currently in place. Administrative complexity depends primarily on

[9] From: 65mtCO_2, converted to mtC by multiplying by 12/44, tonnes of C are then valued with the unit damage values for C, i.e. € 24.7 per tC (with a range of € 8.0 to 57.9 per tC).
[10] Negative costs, imply costs are zero, thus B/C ratios become infinite.

the design. However, based on the fact that inputs tend to be fairly easily measurable it is expected to be relatively simple to implement.
Product tax: based on the experience in Hungary product taxes are feasible. In general though, when a product tax is expressed as a proportion of the product price it is so small that it isn't tangible. However, they could work better at the corporation level. I.e. companies must have an extensive accounting system that could show the amount paid in product taxes.
Recycling credits: Assuming there are similar institutions in the EU15 as in the UK, the administrative complexity is low. This is because recycling credits are simply a transfer of payments from the waste disposal authority to the waste collector. The main difficulty encountered in the UK is the tendency for local authorities not to accept willingly the operation of the market mechanism that allows recyclers and the secondary materials industry to benefit financially from the scheme.
Landfill tax: Administrative complexity is low due to existing institutions, although it does depend on the design. Ad valorem taxes are easiest to administer.
Collection fees: there are a number of variable rate collection fees in existence that demonstrate they are feasible, i.e. The Netherlands, Sweden and Canada. Administration complexity depends on the complexity of the system. Monitoring costs may be high.

2.2.3 Equity criterion

Virgin material tax / product tax: costs are borne by producers, who may pass them on to consumers.We expect this not to be regressive.
Recycling credits have no distributional impact. They can in fact benefit local groups (i.e. charities, youth clubs etc) to collect waste suitable for recycling.
Landfill tax meets equity criterion, costs fall on disposers, these may be passed on to waste generators. In the UK, households pay local authority taxes. The local authority tax is set according to the size of the house, therefore it is not regressive. However, if the local authority tax is regressive then the landfill tax will also be regressive.
Collection fees: shifts costs to those who produce most waste. May be less regressive than the current waste fees

2.2.4 Jurisdictional criterion

Waste management is localised and thus, it is not a central issue. However, competitiveness may be affected with the introduction of virgin materials taxes and product taxes. Such schemes may also constitute a barrier to trade.
Macroeconomic effects

Macroeconomic effects are discussed in *Technical Report on Socio-Economic Trends, Macro Economic Impacts and Cost Interface.*