Evaluation of costs and benefits for the achievement of reuse and recycling targets for the different packaging materials in the frame of the packaging and packaging waste directive 94/62/EC

Final Consolidated Report

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Executive summary

1 OBJECTIVES OF THE STUDY

The Directive on packaging and packaging waste (94/62/EC) provides that Member States set targets[1] for the recovery and recycling of packaging waste to be achieved by 30 June 2001:

- between 50% and 65% recovery by weight of packaging waste,
- between 25% and 45% recycling by weight of packaging waste with a minimum of 15% by weight for each packaging material.

Greece, Ireland and Portugal may postpone the achievement of these targets until 31 December 2005.

The directive also provides that by end 2000 the Council shall fix new targets for the five years following June 2001. During the preparation of a proposal, the Commission was called upon to base new targets on an evaluation of costs and benefits of such new targets. This study was commissioned for this purpose. More specifically, the objective of the study is ***"to perform a cost/benefit analysis of packaging recycling and reuse systems****, including:*

1. *an evaluation of the situation concerning the fulfilment of specific targets as required by the Packaging and Packaging Waste Directive 94/62/EC by the end of the first five-year phase (30/06/2001), i.e. 15% for each packaging material (glass, plastic, paper/board, metals, composites, wood, others),*
2. *a prospective study concerning the fulfilment of higher recycling targets for packaging materials by the end of the second five-year phase (30/06/2006) taking into account limiting factors such as technical feasibility, economic implications and environmental benefits,*
3. *an investigation concerning the possible establishment of reuse targets for the relevant packaging materials by the end of the second five-year phase (30/06/2006) taking into account technical feasibility, costs and environmental benefits, and the development of a methodology for the calculation and monitoring of these targets*."

[1] Member States are permitted to implement higher targets where it can be demonstrated that these can be achieved without disrupting the functioning of the internal market.

2 APPROACH APPLIED AND RESULTS ACHIEVED

2.1 Existing recovery and recycling rates

In a **first step**, the study gives a short overview of the available data on recovery and recycling rates in the Member States.

2.2 Optimal recycling rates

In a **second step**, the study identifies optimal recycling rates by balancing the environmental benefits of recycling with the implementation costs of policy measures. The starting point for this is packaging waste generation, in other words: once a packaging item becomes waste, what should be done with it? Should it go for recycling or should it go to landfill or incineration with energy recovery? The sum of the packaging waste items for which recycling is preferable will determine the optimal recycling rate. A discount is made to take into account realistic participation rates by the population (rates presently achieved by efficient collection schemes).

Identifying whether landfill, incineration or recycling is preferable implies a number of methodological problems. This will concern both the determination of the environmental, social and economic impacts related to the various options in a life cycle assessment (LCA) and the monetary valuation of these impacts in a cost benefit analysis (CBA).

The results of a **life cycle assessment** will vary according to many factors. This study aims at incorporating those parameters in the models as much as possible. But of course it would be impossible to identify and take into account all possible parameters that could influence the results. The principal factors taken into account are :

- A differentiation was made between bring systems (e.g. bottle banks) and kerbside (i.e. door-to-door collection)
- Areas with high and low population densities were studied separately. The population density will determine transport distances, economies of scale etc. It should be noted,

though, that the cost-benefit balance in less densely populated areas is not necessarily worse than in large cities. Furthermore, participation rates and collection results are often better in rural areas than in urban agglomerations. An exception may be very sparsely populated areas or regions with very special geographic conditions (mountains, islands). This could not be studied in detail. However, it should also be taken into account that, by definition, a very small share of a country's population will live in such very sparsely populated areas, even if they constitute a large share of the country's surface. So, also by definition, the correction factor for the full country will be limited.

- The alternative waste treatment method will influence the results significantly. Therefore, recycling was compared both to landfill and incineration (with an average rate of energy recovery). For specific types of packaging (e.g. metals), the recovery of materials from incineration ashes was considered.

A more detailed analysis could refine the results but would unlikely yield a very different overall picture.
As this thorough analysis is very time consuming not all packaging items could be studied in detail :

- The study focused on those items, which are most widespread.
- Items for which the balance was clearly in favour or against recycling were not studied in detail.
- Where the cost-benefit patterns among different applications were likely to be similar, extrapolations were made.

In the **cost-benefit analysis,** the environmental impacts related to collection, sorting, transport, landfilling, incineration (with an average rate of energy recovery) and recycling were translated into monetary values. These monetary values allow the aggregation of and the comparison between internal (financial) and external (environmental and social) costs of the various options considered. The translation into monetary values was done using values from literature based on various valuation techniques. These techniques all imply a high degree of uncertainty as it is often difficult to establish exact values for the different impacts.

Nevertheless, it should be noted that any political decision implicitly means attributing a particular value to environmental impacts, simply by deciding whether a measure is taken or not, in other words whether the benefits are perceived to exceed the costs or not. Although the monetary values attributed to the environmental impacts will remain uncertain, they give the best available information to policy makers. In other words, they give a rough picture of the relationship between the order of magnitude of the environmental benefits and the costs of a political measure.

Subsequently, the internal (financial) and external (environmental and social) costs related to collection, sorting, transport, landfilling, incineration and recycling of the various packaging items under the various conditions were added up to identify the treatment scheme with the lowest total costs. This treatment scheme is then considered preferable for the rest of the study.

For example, as the recycling of PET bottles in high population density areas with landfilling as alternative treatment results has the lowest total costs, all PET bottles arising in areas with these conditions should go to recycling and are counted for determining the optimal recycling rates. However, as there will never be 100% participation by the population, correction is made to include a realistic participation rate based on rates presently achieved by efficient collection schemes. Packaging items, for which under the specific conditions landfilling or incineration is preferable, are not counted for the optimal recycling rates, or in other words the optimal recycling rate for these items is 0%.

The optimal recycling rate is therefore the share of packaging waste among total packaging waste generation for which :

- under the concrete geographical conditions,
- given the alternative disposal method and
- assuming a realistic participation of the population

recycling is preferable to landfilling and incineration.

2.3 Case studies on reuse

For the case studies on reuse, the same methodology was applied, with the exception of the applied system boundaries. In the case of recycling, the point of departure is a packaging waste item and the goal is to determine which waste treatment option has the lowest total costs. In the case of reuse, the question is which packaging system for the delivery of a particular quantity of a beverage has the lowest total cost throughout its life cycle.

3 CONCLUSIONS AND RECOMMENDATIONS

3.1 Reservations using those results

When using the results to inform the revision of the recycling targets in the context of the Directive, the following reservations should be taken into account:

- ✓ CBA (cost-benefit analysis) is not yet a mature instrument, specially concerning the economic valuation of the environmental (and social) impacts which must therefore be considered carefully. CBA is a tool to inform the decision-making process only, it is not a substitute for decision-making.
- ✓ High recycling targets can induce high economic costs reflected in the recycling fees (e.g. green dot) paid. This influences the price of a packaging material and can therefore induce a shift to other materials which may be more environmentally friendly or less environmentally friendly. It should be noted, however, that :
  - There is no proportionality between recycling costs and the levels of the targets
  - If the recycling fees are also used to finance the treatment of the material that is NOT collected selectively, the induced effect on the material choice will be more limited
- ✓ Some results achieved and conclusions drawn (PET, paper & board[2]) are based upon average market prices of the recycled materials over the last years. These materials can be subject to significant price evolutions, which could change the results of the cost benefit balance.
- ✓ The results achieved should not be interpreted and applied too simplistically. Whilst every effort has been made to take into account variable factors that affect the costs and benefits of the recycling, incineration and landfilling schemes, other local factors not considered may also affect the results (e.g. unavailability of local output market for the recycled materials and therefore long transport distances). Nationally or locally, higher or lower recycling rates than the ones suggested by the results may be preferable in some specific cases.

Despite these reservations, the consultants believe that the study gives a good overall picture of the costs and benefits linked to the investigated targets and that the main driving forces for the

[2] The other ones are based on average value over the last 3 years and are thus more stable

results have been covered. Subsequently, the following conclusions are drawn, but with some caution.

3.2 Conclusions

Conclusion 1 Achieved recycling rates are satisfactory

In 1998 most Member States already achieved the recycling rates set in the Packaging Directive. It seems that all Member States will reach the 25% minimum overall recycling target by 2001 and many will have significantly higher recycling rates and exceed the 45% maximum target set by the Directive. Exceptions are the three Member States that had less stringent requirements (i.e. Greece, Ireland and Portugal). The 15% minimum target for each material will be reached in all concerned Member States, with the exception of plastics for which the target might not be reached in several Member States.

Conclusion 2 Selective collection is better for the society with some notable exceptions

Generally speaking the selective collection of both household and industrial packaging is better for the society than its treatment together with unsorted waste. But there are some notable exceptions (see further conclusions).

Conclusion 3 Household packaging: separate kerbside collection is preferable with notable exceptions

For the selective collection of household packaging very often the separate kerbside collection is preferable above the non separate collection and the bring system (and might thus be considered as the "optimum system" among the modelled systems) due to the higher collection rate. Notable exceptions are :

- Glass should be collected from bottle banks (minimum density : 1 bottle bank per 1000 inhabitants)
- The metals
  - should not be collected selectively in areas where the MSW is incinerated with metals recovery, even if the metals recovered after incineration have a lower quality than the metals from a selective collection scheme (the quality difference was taken into account in the economic balance).
  - may also (i.e. not only kerbside) be collected selectively by a bring system in areas with low population density and landfilling (or incineration without metals recovery) of the MSW

  However, as differences are relatively small, this conclusion could possibly be different (i.e. separate kerbside collection could be always preferable) if only the additional cost for separate kerbside collection (cost with metal minus cost without metal) would be taken into account. This has not been investigated.
- There is no evidence to support a mandatory target for the selective collection of Liquid Beverage Cartons, composites and mixed plastics. Again, as the internal costs play a decisive role, this conclusion could possibly be different (i.e. separate collection could be preferable) if only the additional cost for separate kerbside collection (cost with LBC minus cost without LBC) would be taken into account. This has not been investigated
- Plastic bottles should be collected selectively by a bring system in areas where both conditions are fulfilled at the same time :
  - a low population density and
  - the MSW is incinerated with efficient energy recovery

This is summarised below.

	Low population density		High population density	
	Landfill	Incineration	Landfill	Incineration
PET bottles	Kerbside	Bring	Kerbside	Kerbside
Steel packaging	Kerbside or bring	No SC	Kerbside	No SC
Al cans	Kerbside or bring	No SC	Kerbside	No SC
Rigid & semi-rigid Al packaging excluding cans	Kerbside or bring	No SC	Kerbside	No SC
Paper and board packaging	Kerbside	Kerbside	Kerbside	Kerbside
LBC	No SC	No SC	No SC	No SC
Mix plastic packaging	No SC	No SC	No SC	No SC

No SC = no selective collection

The following recycling rates are the ones achievable with the those systems

	Low population density		High population density	
	Landfill	Incineration	Landfill	Incineration
PET bottles	70-80%	35-45%	59-69%	59-69%
Steel packaging	15-60%	80%	40-60%	80%
Al cans	31-55%	76%	45-55%	76%
Rigid & semi-rigid Al packaging excluding cans	3-17%	50%	3-8%	50%
Paper and board packaging	61-71%	61-71%	55-65%	55-65%
LBC	0%	0%	0%	0%
Mix plastic packaging	0%	0%	0%	0%

The results were calculated for mechanical recycling. Based on the sensitivity analysis, there are some indications that some alternative routes could be considered as about equivalent to the mechanical recycling : Supercycle, TBI. However these routes have not been investigated deeply so that these conclusions have to be considered very cautiously.

Conclusion 4 Industrial packaging : separate collection is preferable

For industrial packaging the separate collection for recycling is preferable. Notable exceptions are :

- packaging that contained hazardous waste should be collected separately because hazardous waste should not be recycled
- Companies which produce a very small amount of cardboard waste may put the cardboard waste together with the unsorted waste due to the relatively high additional internal cost (additional container and space use).

Conclusion 5 Revised recycling targets

The recycling rates achievable with the "optimum systems" are summarised in the following tables. They are given :

- per Member State and for the EU as a whole

	Global Target Industrial waste		Global Target Household waste		Global target (Industrial + Household waste)	
	Min	Max	Min	Max	Min	Max
Austria	56%	74%	42%	60%	49%	67%
Belgium	54%	70%	42%	65%	48%	67%
Denmark	54%	70%	53%	66%	53%	68%
Finland	57%	73%	35%	48%	48%	63%
France	53%	72%	45%	68%	50%	70%
Germany	56%	72%	45%	71%	51%	**72%**
Greece	53%	70%	39%	52%	46%	61%
Ireland	50%	67%	27%	38%	**40%**	54%
Italy	54%	71%	44%	65%	49%	68%
Luxembourg	54%	70%	46%	66%	50%	68%
The Netherlands	55%	71%	44%	64%	51%	68%
Portugal	57%	75%	46%	64%	47%	65%
Spain	50%	66%	47%	65%	49%	65%
Sweden	59%	76%	44%	54%	52%	66%
United Kingdom	56%	72%	39%	64%	49%	69%
EU	54%	71%	45%	65%	50%	68%

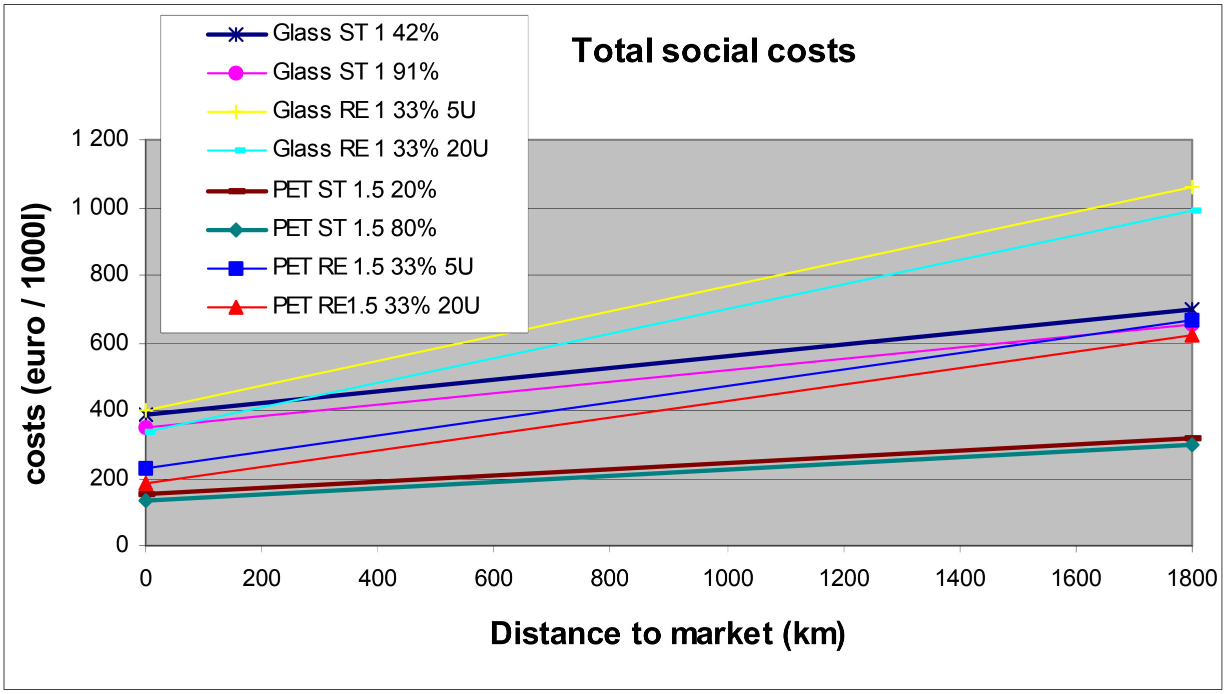
Depending on MS and assumptions, the optimum recycling rate varies from 40% to 72%. There is no uniform optimum recycling rate valid throughout EU. The optimum can vary from MS to MS by as much as 31% (in absolute terms, i.e. from the minimum of the minimum targets to the maximum of the maximum targets).

- per packaging material and for all materials together

	Minimum recycling rate	Maximum recycling rate
Plastic	28%	38%
Steel	60%	75%
Aluminium	25%	31%
Wood	47%	65%
Paper & board	60%	74%
Glass	53%	87%
Composites	0%	0%

The value for plastics would be sensibly lower (21-28%) if the plastic waste composition is the one proposed by APME (see sensitivity analysis).

Conclusion 6 Neither refillable nor non-refillable may be considered generally preferable for beverage packaging



From the analysis performed, it appears that non-refillable (PET) beverage packaging has the lowest total social cost, mainly due to the lower internal cost.

However the variability of some key parameters influencing the results is high for this case study on beverage packaging : the transport distance (see graph above), the number of uses and the internal cost figures (in particular for the deposit system management). So, as costs and benefits of refillable and non-refillable (PET) beverage packaging are in the same order of magnitude, the observations made from the case study may be non applicable in many individual cases. Therefore we conclude that there is no generally preferable system between those 2 types of beverage packaging systems.

The merit of this case study is to prove that the internal cost of a refillable system is considerably higher than of a non-refillable and that this more than compensates the refillable's sometimes lower environmental impacts for short distances. Therefore the general rule should not be to encourage refillable beverage packaging. If applied, a policy favouring refillables should be restricted to the cases where the general rule does not apply due to a particular set of key parameters.

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1 CONSTRAINTS

This study aims to evaluate the costs and benefits of increased recycling targets for packaging waste in the frame of the Packaging and Packaging Waste Directive (94/62/EC). It also investigates the costs and benefits of reusable primary packaging. In order to achieve this, the study applies the technique of life cycle cost benefit analysis (CBA). This is a combined life cycle assessment and economic valuation analysis.

To perform a full cost benefit analysis for all packaging recovery and recycling options in all EU Member States would be an immense task, and its added value might be limited. Due to budget and time restrictions, the consultants have therefore limited the extent of the study so as to produce a representative but accessible analysis. Choices have had to be made which lead to simplifications that do not always represent the full details of real conditions.

It is recognised that there need to be reservations with regards to the validity of the details of the study results. However, it is believed that the study gives a good overall picture of the costs and benefits linked to the investigated targets and that the main driving forces for the results have been covered.

Nonetheless, in order to prevent misunderstandings in the interpretation and application of the study results, it is important to consider a number of constraints imposed by the methodology, the extent of the analysis and the data applied. These are discussed below.

1) Life cycle cost benefit analysis

Life cycle cost benefit analysis (CBA) is a new and developing technique. Although applied for long a.o. in the USA there is no standardised methodology referring to the evaluation of the environmental and social impacts. This study aims to apply the best available knowledge in the field, but debate continues amongst practitioners on key aspects of the approach, including:

- The economic valuations applied to environmental impacts
- The limitations of life cycle assessment methodologies on which CBA is based

The limitations of CBA are discussed in detail in Section 2.3 of this report.

2) Scope of the study

As required by the terms of reference, this study considers the costs and benefits of various treatment options once packaging has become waste. The system boundaries have been drafted to reflect this.

For the investigation of recycling of packaging waste, the system boundaries begin at the point at which packaging is discarded by the final user. For the investigation of reusable packaging, the system boundaries include the entire life cycle of the packaging (including extraction, conversion, filling, and distribution).

The study does not consider upstream issues of material selection. It is recognised that higher recycling targets (and therefore end of life management costs) for one material compared to another may induce a switch from one material to another. This could lead to changes in the competitiveness between different materials and changes in the overall environmental performance of packaging systems. This is not addressed in the study.

3) Limitations of data collection

Data collection and the development and testing of hypotheses was limited due to time and budget constraints:

- Data have been collected from a limited number of sources
- Assumptions and hypothesis have been necessary
- Data from literature could not always been cross-checked with other sources

4) Differences between Member States

The analysis considers the following differences between Member States

- The waste packaging mix available for recycling
- The fraction of a Member State's population living in densely populated areas
- The residual MSW treatment system applied to packaging waste that is not recycled (i.e. landfill or incineration with energy recovery).

The internal costs of operating processes vary across EU. This will influence the costs and benefits of recycling in different Member States. This is addressed where possible by considering data ranges for internal costs.

The case studies do take into account, but not explicitly, the following differences between MS :

- Motivation of the population to participate in recycling schemes

  This significantly influences the range of recycling rates that can be achieved in Member States. The range of recycling rates modelled in the analysis considers the collection and recycling rates that could be achieved if a scheme is implemented where a motivated population exists. This implies an appropriate level of communication of the scheme. However, communication does not guarantee motivation of the population. In some Member States the achievable collection and recycling rates may be lower than the range modelled, in other Member States it may be higher. Cultural differences may play an important role. This is not considered in the analysis.

- Typical family structure

  This effect is reflected in the waste packaging mix and thus taken into account

  Although the packaging mix in each Member State has been considered, the typical family structure has not been considered. This may influence the composition of packaging waste in the household MSW stream, which will ultimately influence collection and sorting of packaging waste arising from households.

The case studies do not take into account the following differences between MS :

- Existence of recycling infrastructures

  The implicit assumption is that if the Directive imposes recycling targets, the availability of recycled material will attract recycling infrastructures and the problem should only be present in a transition period. The legislation stability plays here an important role.

  The capital costs of infrastructure are allocated per ton of material handle, but the analysis does not consider the existence or absence of an existing recycling infrastructure in each MS. A "steady state" analysis is considered. The results do not take into account :

  – the difficulties that some MS may experience in establishing additional infrastructure, and the impact that this may have on costs in individual MS (it is assumed that there is available capacity throughout the EU or that such capacity may be established if there is enough supply of material and sufficient demand for recyclate)

- the time frame over which this infrastructure would need to be established in order to reach higher recycling targets, and the impact that this may have on the costs of implementation in individual MS"

The consultants recognise this as a limitation: possibly some MS could face some technical difficulties in the timing of implementation of the collection system and the building of sorting and recycling facilities. So the limitation concerns the timing of the new targets, not their values.

However, to perform the analysis of the feasible time schedule, building in supply and demand factors and time dimensions, would have required more time and resource than could be made available for the project, and would have demanded detailed financial and market data which is unlikely to have been available.

- Specific geographical problems , such as mountainous terraionareas, islands, areas with a very low population density.

The study does not consider specific geographical problems imposed by adverse weather conditions or isolated communities such as island or mountain based communities.

The implicit assumption is that only a minor fraction of the population lives in such areas so that even if their optimum recycling rates would sensibly differ from the rest of the areas, their influence on the optimum recycling targets at a MS level would be rather limited. The authors agree that this assumption might be inappropriate for some countries (e.g. Spain, Finland, Greece). This has NOT been investigated.

2 INTRODUCTION AND OBJECTIVES

The Directive on packaging and packaging waste (94/62/EC) provides that Member States set targets[1] for the recovery and recycling of packaging waste to be achieved by 30 June 2001:

- between 50% and 65% recovery by weight of packaging waste,
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Greece, Ireland and Portugal may postpone the achievement of these targets until 31 December 2005.

The directive also provides that by end 2000 the Council shall fix new targets for the five years following June 2001. During the preparation of a proposal, the Commission was called upon to base new targets on an evaluation of costs and benefits of such new targets. This study was commissioned for this purpose.

This section describes the study's objectives, scope and the concept of cost benefit analysis.

2.1 Objectives and scope of the study

As stated in the call for tender, "***The objective of the study is to perform a cost/benefit analysis of packaging recycling and reuse systems****, including:*

1. *an evaluation of the situation concerning the fulfilment of specific targets as required by the Packaging and Packaging Waste Directive 94/62/EC by the end of the first five-year phase (30/06/2001), i.e. 15% for each packaging material (glass, plastic, paper/board, metals, composites, wood, others),*
2. *a prospective study concerning the fulfilment of higher recycling targets for packaging materials by the end of the second five-year phase (30/06/2006) taking into account limiting factors such as technical feasibility, economic implications and environmental benefits,*
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account technical feasibility, costs and environmental benefits, and the development of a methodology for the calculation and monitoring of these targets."

A possible approach was to start from different recycling rates, to determine the way to achieve them and to determine their costs and benefits. The approach used in this study is different: we first considered the different possible systems, we determined their optimum organization, calculated their costs and benefits and then considered the recycling rates achievable by the "cheapest" system.

The study aims to cover:

- All fifteen Member States
- Each individual packaging material (glass, plastic, paper/board, metals, composites, wood, others)
- All packaging applications (primary, secondary, tertiary)
- Alternative packaging collection and reprocessing options

However, in order to achieve the analysis within the budget and time constraints, it has been necessary to make assumptions and hypotheses which limit the scope of the analysis (see chapter 1 of this report).

To achieve these objectives, the consultants apply a stepwise approach, as presented in Figure 1, p.27 below.

2.1.1 Existing recovery and recycling rates

In a **first step**, the study gives a short overview of the available data on recovery and recycling rates in the Member States.

2.1.2 Optimal recycling rates

In a **second step**, the study identifies optimal recycling rates by balancing the environmental benefits of recycling with the implementation costs. The starting point for this is packaging waste generation, in other words: once a packaging item becomes waste, what should be done with it? Should it go for recycling or should it go to landfill or incineration with energy recovery? The sum of the packaging waste items for which recycling is preferable will determine the optimal recycling rate. A discount is made to take into account realistic participation rates by the population (rates presently achieved by efficient collection schemes).

Identifying whether landfill, incineration or recycling is preferable implies a number of methodological problems. This will concern both the determination of the environmental, social and economic impacts related to the various options in a life cycle assessment (LCA) and the monetary valuation of these impacts in a cost benefit analysis (CBA).

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- Areas with high and low population densities were studied separately. The population density will determine transport distances, economies of scale etc. It should be noted, though, that the cost-benefit balance in less densely populated areas is not necessarily worse than in large cities. Furthermore, participation rates and collection results are often better in rural areas than in urban agglomerations. An exception may be very sparsely populated areas or regions with very special geographic conditions (mountains, islands). This could not be studied in detail. However, it should also be taken into account that, by definition, a very small share of a country's population will live in such very sparsely populated areas, even if they constitute a large share of the country's surface. So, also by definition, the correction factor for the full country will be limited.
- The alternative waste treatment method will influence the results significantly. Therefore, recycling was compared both to landfill and incineration (with an average rate of energy recovery). For specific types of packaging (e.g. metals), the recovery of materials from incineration ashes was considered.

A more detailed analysis could refine the results but would unlikely yield a very different overall picture.

As this thorough analysis is very time consuming not all packaging items could be studied in detail :

- The study focused on those items, which are most widespread.
- Items for which the balance was clearly in favour or against recycling were not studied in detail.
- Where the cost-benefit patterns among different applications were likely to be similar, extrapolations were made.

In the **cost-benefit analysis,** the environmental impacts related to collection, sorting, transport, landfilling, incineration (with an average rate of energy recovery) and recycling were translated into monetary values. These monetary values allow the aggregation of and the comparison between internal (financial) and external (environmental and social) costs of the various options considered. The translation into monetary values was done using values from literature based on various valuation techniques. These techniques all imply a high degree of uncertainty as it is often difficult to establish exact values for the different impacts.

Nevertheless, it should be noted that any political decision implicitly means attributing a particular value to environmental impacts, simply by deciding whether a measure is taken or not, in other words whether the benefits are perceived to exceed the costs or not. Although the monetary values attributed to the environmental impacts will remain uncertain, they give the best available information to policy makers. In other words, they give a rough picture of the relationship between the order of magnitude of the environmental benefits and the costs of a political measure.

Subsequently, the internal (financial) and external (environmental and social) costs related to collection, sorting, transport, landfilling, incineration and recycling of the various packaging items under the various conditions were added up to identify the treatment scheme with the lowest total costs. This treatment scheme is then considered preferable for the rest of the study.

For example, as the recycling of PET bottles in high population density areas with landfilling as alternative treatment results has the lowest total costs, all PET bottles arising in areas with these conditions should go to recycling and are counted for determining the optimal recycling rates. However, as there will never be 100% participation by the population, correction is made to include a realistic participation rate based on rates presently achieved by efficient collection schemes. Packaging items, for which under the specific conditions landfilling or incineration is preferable, are not counted for the optimal recycling rates, or in other words the optimal recycling rate for these items is 0%.

The optimal recycling rate is therefore the share of packaging waste among total packaging waste generation for which :

- under the concrete geographical conditions,
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recycling is preferable to landfilling and incineration.

2.1.3 Case studies on reuse

For the case studies on reuse, the same methodology was applied, with the exception of the applied system boundaries. In the case of recycling, the point of departure is a packaging waste item and the goal is to determine which waste treatment option has the lowest total costs. In the case of reuse, the question is which packaging system for the delivery of a particular quantity of a beverage has the lowest total cost throughout its life cycle.

2.2 Contractor's tasks

As stated in the call for tender, the contractor's tasks are the following ones :

"*Task 1: Data compilation*

The contractor shall perform a review of the relevant studies in the field of packaging waste management systems including cost-benefit analyses.

The contractor shall also use the data provided by Member States according to the provisions of the packaging and packaging waste Directive 94/62/EC and the Commission Decision 97/138/EC establishing the database formats. This data covers the calendar year 1997 and includes figures on the quantity of packaging material placed on the market, re-used, recycled, recovered and disposed of.

The study shall consider both packaging waste treated within the territories of the Member States as well as exported quantities. Information shall be given on the countries of destination of exports, the used treatment methods and the monitoring systems applied in these countries.

Data concerning the different packaging materials shall take into account their source (municipal, industrial,...) and their utilisation nature (primary, secondary and tertiary packaging).

Task 2: Analysis of collection, recycling and reuse systems

The different existing collection and sorting systems shall be described in terms of costs and effectiveness (collection of packaging with the general municipal waste and further sorting; selective collection through kerbside or drop-off systems; other options).

The different existing treatment routes for recycling shall be described in as much detail as possible in terms of capacities, costs and environmental impacts.

Special emphasis shall be put on the description of the different recycling processes for plastics[2]*, which shall be defined as clearly as possible. In that context, the analysis will consider as far as possible the different plastics packaging materials split up as relevant in PE (polyethylene), LDPE (low density polyethylene), HDPE (high density polyethylene), LLDPE (linear low density polyethylene), PET (polyethylene terephtalate), PP (polypropylene), PS (polystyrene), PVC (polyvinylchloride),...*

Existing deposit systems for returnable and reuse packaging materials shall be investigated.

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[2] "mechanical *recycling"* where plastics are reprocessed with unchanged chemical structure;
•*"chemical recycling"* (also known as feedstock recycling) where the polymeric chemical structure is broken down to monomer or to a more basic chemical structure, including inter alia de-polymerisation processes such as methanolysis, glycolysis. aminolysis and acidolysis, thermal cracking processes (as Veba, BASF and BP processes), pyrolysis, gasification (Texaco process) and blast furnace process (use of plastics as reductor agent);
"pseudo recycling processes" consisting in an energy recovery from plastics packaging, waste after "mechanical recycling" and/or "chemical recycling"

Task 3: Costs and benefits of packaging waste management according to current and possible future targets

The contractor shall establish an appropriate general method of calculating costs and benefits of packaging waste management. This method shall then be applied to the situation in the fifteen Member States according to the scenarios described in tasks 3.1, 3.2 and 3.3. Particular emphasis shall be put on plastics and composites packaging.

- *The financial balance shall identify all relevant costs related to the collection and treatment of packaging waste according to the various options, identify possible revenues from the sale of secondary materials and calculate the reduced costs of municipal waste management as a result of the separate collection.*

- *The environmental evaluation shall identify the amounts of the primary raw materials that can be saved through the re-use and recycling of packaging according to the various possible targets. The associated change of environmental impacts (in particular: climate change, acidification, tropospheric ozone, eutrophication, toxic substances dispersion and disposal of final solid waste) shall be quantified as far as possible in monetary terms of avoided externalities. In the absence of monetary figures, quantitative values of avoided pollution shall be given.*

- *Employment and social effects shall be described and quantified as far as possible.*

The contractor shall also perform a sensitivity analysis on factors that might substantially influence the results of the cost-benefit analysis.

Task 3.1: fulfillment of specific recycling targets as required by the Packaging Directive by June 2001, i.e. 15% for each packaging material,

The contractor shall make an evaluation of the situation in the different Member States:

- *confirming that the targets foreseen will be met*
- *and describing possible positive or negative variations.*

Task 3.2: fulfillment of higher recycling targets by June 2096.

The contractor shall, in agreement with the Commission, identify a set of meaningful targets to be achieved by June 2006 for the various materials with a view to maximising environmental *benefits. A minimum of eight relevant case studies shall describe possible combinations of these targets and investigate different optional routes to achieve these targets. Again, particular emphasis should be put on the recycling of plastics and composite packaging.*

The contractor shall determine limiting factors for the achievement of these higher targets, such as technical, ecological, economic and practical ones in terms of collection. The contractor shall discuss possible solutions to be applied to these limiting factors. Possible Community and national measures that are likely to improve the efficiency of the systems shall be identified. Measures might include in particular legislative and voluntary initiatives, financial assistance, innovation incentives, etc.

***Task 3.3**: establishment of reuse targets*

The report shall include information on existing deposit systems on packaging. It shall describe and evaluate these systems according to the following factors: materials covered, return rates/number of observed rotations, reuse/recycling levels achieved, costs, system management and other issues that are of interest with respect to the current situation and future development of these systems.

The contractor shall make an evaluation of the technical feasibility, the costs and the environmental benefits in order to set reuse targets by June 2006 for the relevant packaging materials. A methodology for the calculation and monitoring of these targets shall be proposed."

2.3 General methodological approach – Life cycle cost benefit analysis

The general approach applied is based on the principle of life cycle cost benefit analysis (CBA). This section of the report briefly describes the concept of CBA. A detailed description of the methodology applied in this study is provided in Section 3 of this report.

What is CBA?

CBA is an economic evaluation tool used to compare the costs against the benefits of different activities. Within the context of policy development, CBA attempts to quantify the total costs and total benefits of a given policy option in order to determine whether the policy is worth pursuing.

The policy is considered from the social welfare perspective. An action is considered worthwhile if the total benefits to society outweigh the total costs to society.

These costs and benefits must be considered across the whole life cycle of the system affected by the policy decision. Therefore, life cycle cost benefit analysis combines aspects of financial cost benefit analysis with the economic valuation of the environmental impacts which are determined by life cycle assessment techniques.

Why use CBA?

Environmental policies are pursued in order to provide environmental protection and to reduce environmental impacts of economic activities. For example, policies to reduce the effects of global warming may be quantified in terms of avoided greenhouse gas (measured in kilograms of CO_2 equivalents). These benefits are known as externalities, as they are external to the traditional economic model. Environmental impacts are one form of externalities. Externalities are changes in the social welfare that are not taken into account in market prices. In other words, the effects of environmental impacts are borne by society, either through abatement costs paid by actors other than the polluter (e.g. by the taxpayer via government budgets) or through reduced environmental quality. Environmental policies can reduce such externalities.

However, in addition to these environmental benefits, an environmental policy decision will also incur implementation costs. Different policy options will incur different cost implications. The internal costs of implementation are known as internalities, as they are internal to the traditional economic model. The benefits of reducing such externalities need to be compared to the implementation costs of such policies. The social optimum occurs where the social benefits of the policy equal its social costs. In the concrete case, this is where the social benefits of recycling equal its social costs.

Politicians and decision makers seek to pursue policies that provide good value for money by balancing the (external) environmental objectives / benefits without incurring disproportionate with the (internal) implementation costs. A quantitative comparison of the costs and benefits of environmental policies can only be achieved if the internalities and externalities are measured in a common unit. CBA seeks to do this by valuing in monetary terms the externalities, and comparing these against the internal costs of implementation. In this way, we gain insight into the trade-offs (within and between economic costs and environmental benefits) that are inevitably made when selecting and implementing policies.

Limitations to CBA

CBA is a new and developing technique. As with all tools and techniques, there are limitations to the methodology. The limitations of CBA should be recognised before the methodology is applied:

- Ethical issues

Many critics of CBA question the underlying ethics of monetary valuation of environmental impacts. They believe that the environment is something sacred upon which it is not acceptable to place a monetary value. It needs to be underlined, though, that every political decision on environmental measures implicitly gives a value to the environment. The question is whether this is done on the basis of transparent information or not.

- Methodological limitations of LCA

The environmental analysis that is performed prior to the economic valuation of the environmental impacts is based on life cycle assessment (LCA) methodologies. LCA has been subject to international standardisation efforts, but some methodological limitations persist:

- The nature of choices and assumptions made in LCA (e.g. system boundary setting, selection of data sources and impact categories) may be subjective
- Models used for inventory analysis or to assess environmental impacts are limited by their assumptions , and may not be available for all potential impacts
- Results for LCA studies focusing on global or regional issues may not be appropriate for specific local applications
- The accuracy of LCA studies may be limited by accessibility or availability of relevant data, or by data quality and data gaps
- A lack of spatial and temporal considerations in inventory data that are subsequently used for impact assessment may introduce uncertainty to the results

- Achieving economic valuation of environmental impacts

Not every externality can be valued in monetary terms at present:

- Several external effects are difficult to measure
- Some environmental impacts are too site specific to be reliably transferred from specific studies to a general CBA methodology
- Studies to determine economic valuations have only been conducted in a limited number of areas. Willingness-to-pay for prevention of damages to the environment may vary between geographical populations, but it is necessary to rely on the concept of benefit transfer in order to develop a general CBA methodology.

- Methodological difficulties arising from attempts to perform monetisation

Where monetisation can be performed, the reliability of the values derived may be questioned. A variety of techniques can be applied to derive economic valuations. In many cases, application of different techniques results in conflicting valuations being achieved, suggesting inherent bias in valuation methodologies. The alternative techniques that can be applied are described in detail in **Annex 4: Economic valuations applied – sources and derivation**.

- Increasing difficulties of isolating external costs

Increasingly, national environmental policies have attempted to internalise some aspects of external costs. For example, emission permits and landfill taxes effectively internalise some elements of pollution. The charges for these permits and taxes have rarely been based on a detailed evaluation of the external costs of the avoided environmental impact. These charges should not be included when performing CBA, but it is not easy to accurately determine the level of internalisation. This may lead to some double counting in the methodology.

- Quantifying indirect and secondary effects

The difficulties of quantifying indirect costs and secondary effects means that many studies focus only on the direct costs. This limited approach could have a significant influence on the true "social cost". In some cases, wider effects can only be taken into account by inclusion of broad assumptions, which may be limiting. Indirect and secondary effects have not been considered in this study. A discussion of the effect of such indirect and secondary effects can be found in European Commission 1999[3].

How to use CBA

This type of approach enables decision-makers and stakeholders to better understand the trade-offs within and between economic costs and environmental benefits that are inevitably made when selecting policies. **Thus, CBA makes decision-making more transparent. It is an aid to the decision-making process, not a substitute for it**. The decision-maker must still judge how to weigh up environmental effects, economic costs and the distributional impacts of the different policy options in order to select the preferred option

It is important to recognize CBA as a useful tool rather than a decision rule. By asking the right questions it opens up the discussion and identifies key issues.

Relationship of CBA to other economic evaluation tools

CBA considers the micro-economic effects of the policy in detail. This is known as a "bottom-up" approach. However, in considering these micro-economic effects, broader consequences of the policy decision should not be overlooked. In some cases, it may be appropriate to support CBA with some form of "top-down" macro-economic analyses.

Such macro-economic analysis techniques may consider the impacts of policy on economic indicators such as GDP, inflation rate, and the trade balance. This type of analysis is most appropriate for policy instruments with potentially significant macro-economic effects.

Examples of macro-economic tools include:

- General and partial equilibrium models
- Input-Output models
- Application of multipliers.

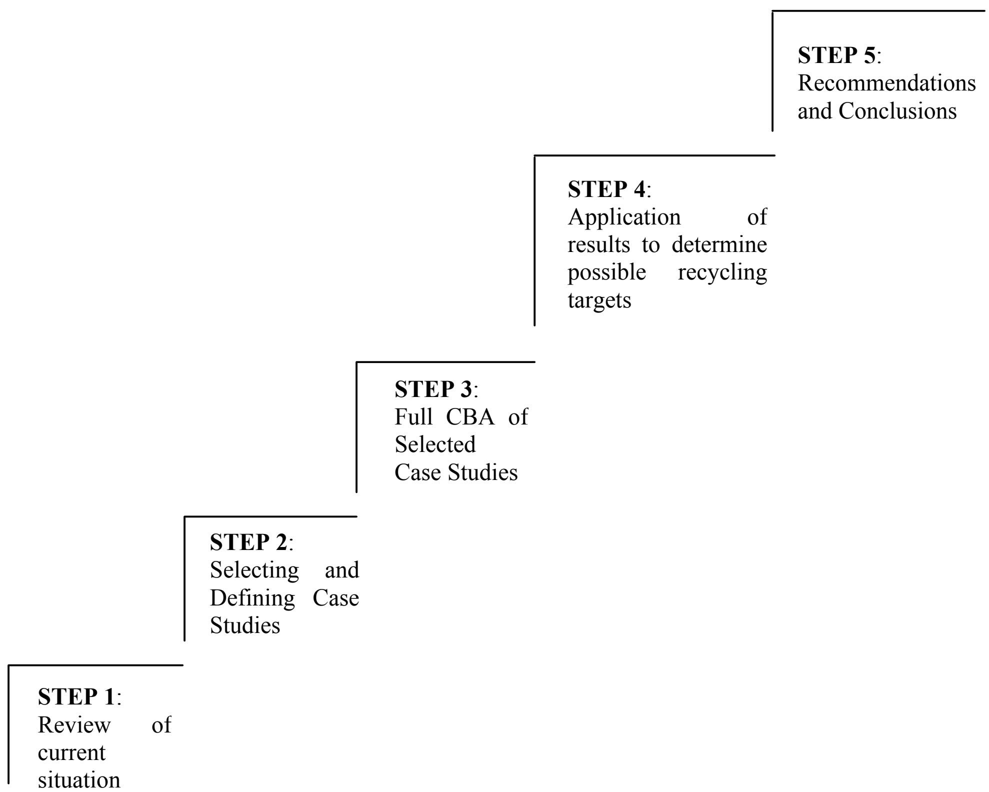
[3] Induced and opportunity cost and benefit patterns in the context of Cost-Benefit Analysis in the field of environment, RPA for the European Commission, 1999.

However, macro-economic analyses in isolation may not be appropriate for assessing the potential benefits of specific environmental policy measures. Statistics such as GDP are measures of the volume and structure of market transactions rather than measures of welfare or the efficiency of resource use. Macro-economic analyses sacrifice technical detail for greater spatial scope

3 DETAILED METHODOLOGY

This section describes the methodological approach applied in order to fulfil the study objectives. The approach has been broken down into a series of steps, as described in Figure 1. Where appropriate, the application of the methodology has been demonstrated through reference to the calculations performed for a specific case study (PET bottles).

Figure 1 : Stepwise approach of the methodology



Each of the Steps is described in greater detail in the following sections.

3.1 Review of the current situation (step 1)

In Step 1, the current packaging waste recovery and recycling situation in Europe is reviewed to determine:

- The performance of Member States against the current targets for packaging waste recovery and recycling

- The critical factors that limit the levels of recycling or reuse that can be achieved

3.1.1 Current performance of Member States

Data and forecasts have been collected for the years 1997, 1998 and 1999.

The collected data is classified by the following parameters:

- ♦ Classification of the data per year
    - ♦ Classification according to waste production (packaging brought on the market), and recycled amount, for individual Member States
        - ♦ Data were collected for the material classes as detailed as possible (as much sub-divisions according to material applications as possible)
            - ♦ glass,
            - ♦ plastics,
            - ♦ paper & cardboard,
            - ♦ metals,
            - ♦ composites,
            - ♦ wood,
            - ♦ other packaging materials

3.1.2 Critical factors limiting recycling and reuse

The critical factors limiting the levels of recycling or reuse that can be achieved for a material and/or by packaging application are classified according to their specific nature:

- ♦ Technical
- ♦ Economic
- ♦ Marketing

The critical factors for each material have been identified through a combination of literature search and discussion with stakeholders.

3.2 Selecting and defining the case studies (step 2)

Due to the constraints of time and budget, the full cost benefit analysis can only be applied to a limited number of case studies. The aim of Step 2 of the methodology is to select appropriate case studies for full cost benefit analysis and to define the specific process tree for each case study.

3.2.1 Select packaging applications for full cost benefit analysis

The selection of packaging applications for full CBA is ultimately subjective, but in determining the case studies the following criteria have been considered:

- Packaging applications are not considered for full CBA where there is a general consensus among stakeholders that the recycling rate should be high
- Packaging applications which contribute to the production of the highest quantity (by weight) of packaging waste in the EU are favoured
- Special attention is given to plastics and composites[4]
- Some reuse systems must be included
- Efforts are made to ensure that a sufficient diversity of packaging materials and applications are considered
- Efforts are made to ensure that there is a sufficient quality of data to complete each CBA

Based on the consideration of these criteria, the following case studies have been selected.

[4] As required by the EC in the call for tender

Table 1 : Recycling case studies selected for full CBA

N°	Material	Case study	Industrial/household
1	Plastics	LDPE films	Industrial
2	Paper/cardboard	Corrugated board	Industrial
3	Plastics	PET bottles	Household
4	Plastics	Mixed plastics	Household
5	Steel	All applications	Household
6	Aluminium	All rigid and semi-rigid applications	Household
7	Aluminium	All flexible applications	Household
8	Paper/cardboard	All applications	Household
9	Composites	Liquid beverage cartons (LBC)	Household
10	Glass	Beverage bottles	Household

Note: the two aluminium systems can be done as a single scenario for total aluminium

Table 2 : Reuse case studies selected for full CBA

N°	Material	Case study	Industrial/household
1	Glass	Single trip beverage bottles and reusable beverage bottles	Household
2	PET	Single trip beverage bottles and reusable beverage bottles	Household

The recycling case studies selected represent a significant fraction of the total packaging waste stream. The following important packaging waste flows have been excluded from the full CBA case studies, as there is a general consensus that high reuse and recycling rates should be achieved for these applications:

- Industrial steel applications, such as drums and pails (due to the high economic value of the material high rates of reuse, reconditioning and recycling are already achieved for these applications)

- Wood packaging applications, such as pallets - high levels of reuse, reconditioning and recycling of wood pallets and other wood packaging applications are already achieved
- Rigid industrial packaging applications, such as crates, drums and pails

3.2.2 For each packaging material / application selected for full CBA, define the process tree

The process tree defines the individual unit processes and the system boundaries considered in the analysis. A unit process is the smallest portion of a system for which data are collected when performing an LCA study. The system boundary is the interface between a system and the environment or other systems. Data is only collected for those unit processes inside the system boundary.

The full process trees for each case study are presented and described in **Annex 1: Process trees and system descriptions** of this report. The incineration and landfill models considered are described in **Annex 2: Incineration and landfill models**.

3.2.2.1 Recycling case studies

Figure 2 and Figure 3 show the generic process trees for the recycling case studies. The system boundaries begin at the point at which the packaging material is discarded by the final holder. The system boundaries end at the point of final disposal (i.e. landfill or incineration) or at the point at which the material directly replaces a virgin product/material. The point at which the material directly replaces a virgin product/material may be immediately after sorting or may be after some reprocessing of the sorted packaging waste. Credit for offset virgin production is included in the system boundaries.

Within the system boundaries, the operation of each unit process is considered. This includes all waste management, reprocessing, transport, and energy production unit process. The system boundaries include the capital necessary to provide these unit processes.

Figure 2 : generic process tree for the recycling case study (household packaging)

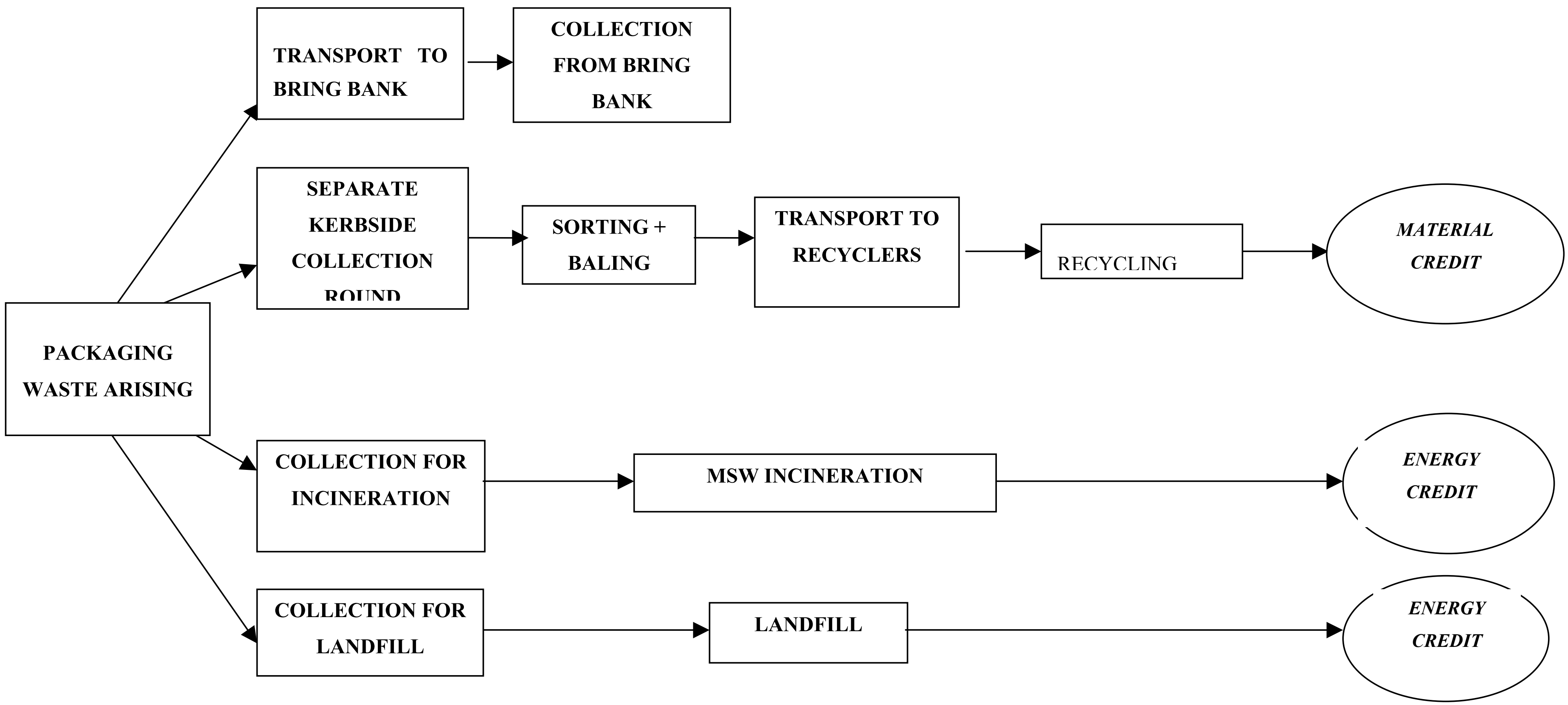
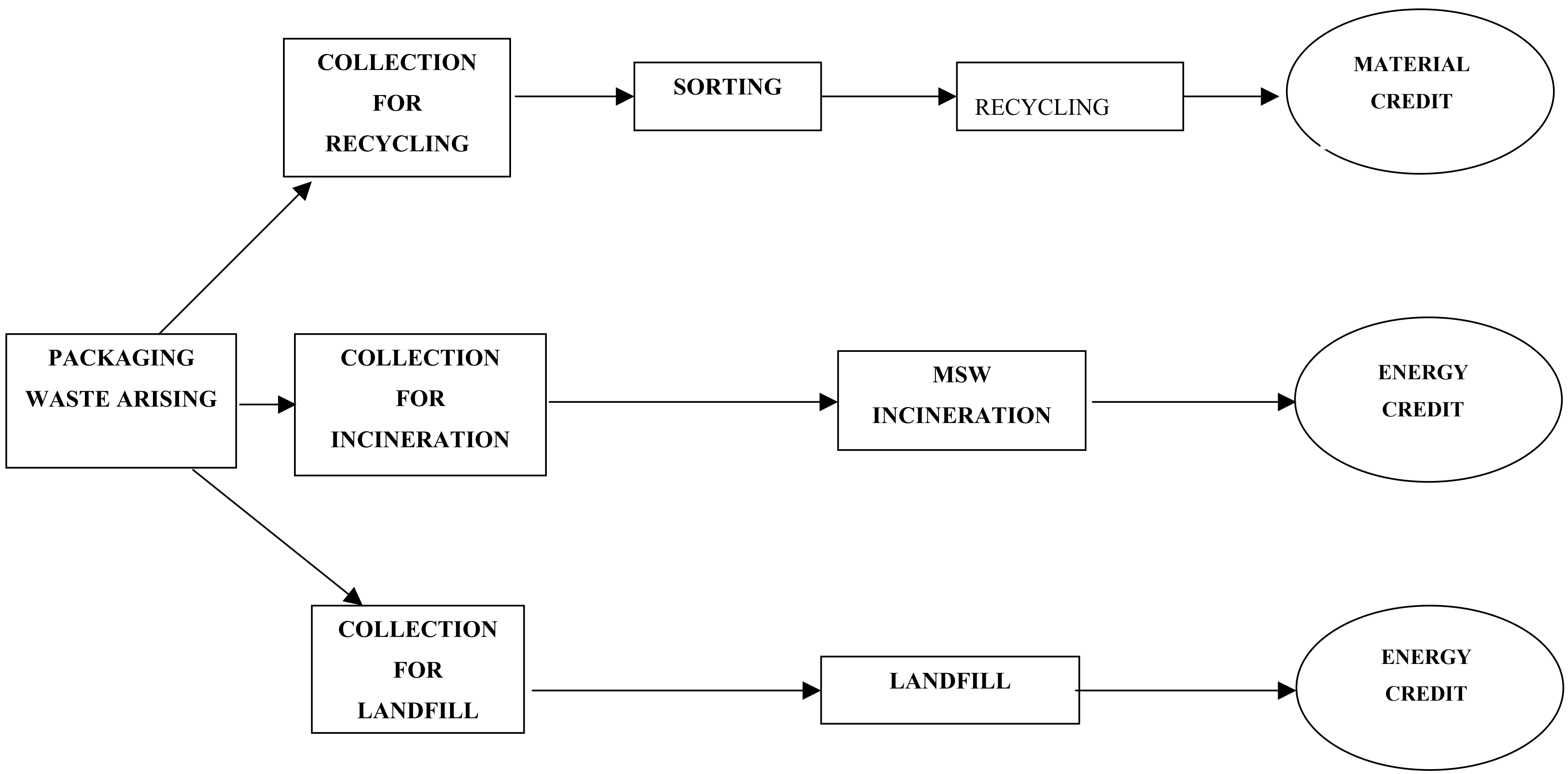


Figure 3 : Generic process tree for the recycling case study (industrial packaging)



3.2.2.2 Reuse case studies

The system boundaries begin at the extraction of raw materials for the production of packaging. The system boundaries end at the point of final disposal (i.e. landfill or incineration) or at the point at which the material directly replaces a virgin product/material. Within the system boundaries, the operation of each unit process is considered. This includes all production, waste management, reprocessing, transport, and energy production unit process, including those associated with the collection, sorting, and washing of packaging for reuse. The system boundaries include the capital necessary to provide these unit processes.

3.3 Full cost benefit analysis of case studies (step 3)

This section of the methodology describes how CBA techniques are applied to the selected case studies. Life cycle cost benefit analysis (CBA) is an economic evaluation tool used to compare the costs against the benefits of different activities. CBA attempts to quantify the total social costs and total social benefits of an activity.

The total social costs of an activity are the sum of the internal costs and external costs. Internal costs are those costs internalised to the economy. External costs are the costs that arise when the social or economic activities of one group of people have an impact on another, and when the first group fails to fully account for their impact. For example, external costs arise if an economic activity causes environmental damage and the polluter does not pay for clean up or fails to compensate those who suffer from this damage.

The classic example of an external effect is that of an upstream factory polluting a river in a way that has a negative impact on catches in a downstream fishery. In deciding upon how much it will produce and consequently how much it will emit to the river, the upstream factory will not take this effect into account.

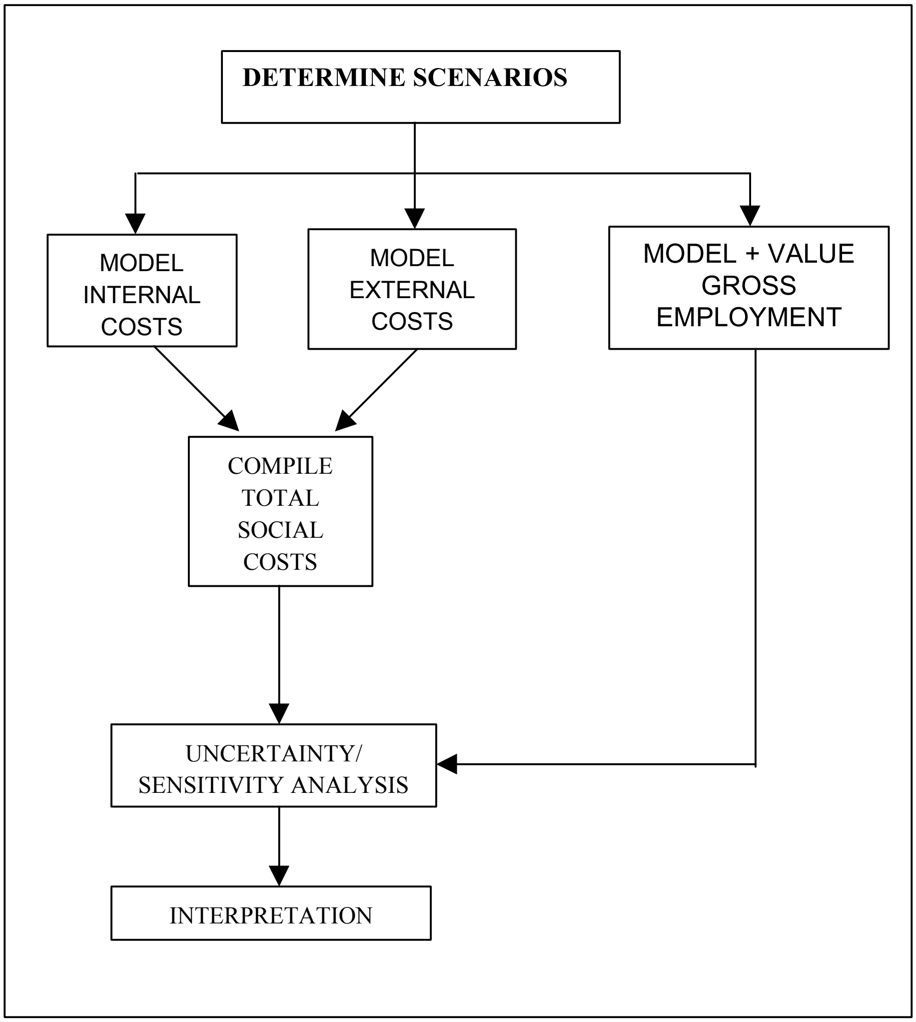
To determine the internal and external costs and benefits, CBA combines aspects of financial cost benefit analysis with the economic valuation of environmental impacts as determined by life cycle assessment techniques.

Life cycle assessment is a technique for assessing the potential environmental impacts of a product or process by compiling an inventory of relevant inputs and outputs of the system and subsequently evaluating the potential environment impacts associated with those inputs and outputs.

Economic valuation is a technique for determining the monetary value of a specific environmental impact. This facilitates the direct summation of different environmental impacts for comparison against the internal costs and benefits. It also allows to take into account some types of local environmental impacts that are usually not considered in LCA due to the lack of valuation methodology, in particular for transport (traffic congestion, traffic accidents, traffic noise) and disaminity (odours, vibrations, harmful animals, fear, dust…).

The full CBA of the case studies is completed in a series of sub-steps as illustrated in Figure 4.

Figure 4 : Full CBA of case studies – sub-steps



Each sub-step is described in detail below.

3.3.1 Determine scenarios

The specific scenarios to be considered in each case study must be determined. This sub-step describes how the scenarios are derived.

3.3.1.1 Recycling case studies

For each household packaging waste case study, scenarios are determined according to three key parameters:

- Population density (i.e. high or low population density)
- National municipal solid waste (MSW) management option available as an alternative to recycling (i.e. landfill or incineration)

- Where recycling is considered, the type of selective collection scheme (i.e. bring scheme or separate collection)

Thus, for the **household packaging waste case studies** the following combinations of scenarios are possible:

Table 3 : Scenarios relating to household packaging waste

Population density	Waste management of MSW	Collection scheme	Recycling rate
High	Landfill	None	0%
High	Landfill	Bring	W to X%
High	Landfill	Separate kerbside collection	Y to Z%
High	Incineration	None	0%
High	Incineration	Bring	W to X%
High	Incineration	Separate kerbside collection	Y to Z%
Low	Landfill	None	0%
Low	Landfill	Bring	A to B%
Low	Landfill	Separate kerbside collection	C to D%
Low	Incineration	None	0%
Low	Incineration	Bring	A to B%
Low	Incineration	Separate kerbside collection	C to D%

For each case study, the specific recycling rates considered are those that are achievable in a steady state situation applying the selective collection system with an efficient management, i.e. considering:

- efficient organization of the scheme, e.g. :
  - frequency (e.g. once every 2 weeks for kerbside collection of light packaging) or
  - density (e.g. one glass bottle bank for 1000 or less inhabitants)
- efficient communication of the scheme to potential participants
- a scheme in existence for at least 3 years (steady state achieved).

For each **commercial & industrial packaging waste case study**, the scenarios are determined only according to the solid waste management option available as an alternative to recycling (i.e. landfill or incineration). Thus, for industrial & commercial packaging waste case studies the following combinations of scenarios are possible:

Table 4 : scenarios relating to industrial & commercial packaging waste

Waste management of MSW	Collection scheme	Recycling rate
Landfill	None	0%
Landfill	Source separated selective collection	U to V%
Incineration	None	0%
Incineration	Source separated selective collection	U to V%

Again, for each case study, the specific recycling rates considered are those that are achievable applying the selective collection system with an efficient management, i.e. considering:

- efficient collection frequency (no full containers)
- efficient communication of the scheme to workers.

The recycling rates considered for the household packaging case studies are summarised in Table 5.

Table 5 : Achievable recycling rates for household packaging waste (%)

		High density		Low density	
	%	Kerb.	Bring	Kerb.	Bring
Plastics	PET bottles	59-69	22-32	70-80	35-45
	LPDE films	20-25	20-25	20-25	20-25
	HDPE bottles	48-58	17-27	57-67	28-38
	Mixed plastics - mech. recycling	5-10		5-10	
	Mixed plastics – blast furnace	60-80		60-80	
Steel*		40-60	15-21	40-60	15-21
Aluminium*	Cans	45-55	31-41	45-55	31-41
	Other rigid and semi-rigid packaging	6-16	3-8	7-17	3-10
	Flexible packaging	0	0	0	0
Wood		0	0	0	0
Cardboard		55-65	19-29	61-71	25-35
composites	LBC	55-65	24-34	55-65	24-34
	Mainly based on plastic	20-25	20-25	20-25	20-25
	Mainly based on cardboard	20-25	20-25	20-25	20-25
	Mainly based on Al	20-25	20-25	20-25	20-25
Glass			42-91		73-83
Other		0	0	0	0

* A possible reason for the relatively low values of the achievable rates for the metals (specially beverage cans) is the fact that a large part is consumed in the industry and may not enter the selective collection schemes for household packaging waste. Collections schemes of household packaging in industry have not been investigated.

The sources of those achievable recycling rates are given below. Only the sources that refer to efficient selective collection systems (see above) were considered.

	Data Sources	Comments
Plastics	Interview of Eco-Emballages Extrapolation of data published in the Annual Report of the Compliance Schemes Potential for post-user plastic waste recycling, Sofres-TNO, commissioned by APME, March 1998	Range of ± 5% was applied in order to take into account the differences between MS.
Steel	Interview of APEAL Extrapolation of data published in the Annual Report of the Compliance Schemes	Range was discussed with APEAL.
Aluminium	Interview of EAA Extrapolation of data published in the Annual Report of the Compliance Schemes Interview of Eco-Emballages	Range of ± 5% was applied in order to take into account the differences between MS
Cardboard	Interview of Eco-Emballages and CEPI Extrapolation of data published in the Annual Report of the Compliance Schemes	Range of ± 5% was applied in order to take into account the differences between MS
LBC	Interview of ACE Extrapolation of data published in the Annual Report of the Compliance Schemes "What happens to used beverage cartons ?", brochure made by Tetra Pak™, January 2000	Range of ± 5% was applied in order to take into account the differences between MS
Glass	Glass recycling in European Countries – 1999, data provided by FEVE, November 2000 Eco-Emballages, interview of stakeholders	In case of low pop. density a range of ± 5% was applied in order to take into account the differences between MS.
Composites other than LBC	Assumption	
Wood and other materials	Assumption	Insufficient amount to be collected selectively

Example: Scenarios determined for the PET bottles case study

See Table 14, p. 69

Industrial packaging waste is subdivided into 3 categories (Table 6):

- waste that can't be recycled for technical reasons (contamination, has contained hazardous waste ,…)
- waste that can't be recycled for economical reasons, i.e. when the industry does not produce a sufficient amount packaging waste (assumption : 5% of the non contaminated amount)
- waste that should be recycled

Table 6 illustrates the analysis of industrial plastic packaging, which was performed in collaboration with EuPC.

Table 6 : Determination of the potential recycling rate according to the application

	%		%		%		achievable recycling rate	weighted target
Drums (100% HDPE)	30%	small (<60l)	20%	hazardous			0%	0%
			80%	non hazardous	15%	not recyclable	0%	0%
					85%	recyclable	95%	19,4%
	70%	large (>60l)	100%	reuse			10%	7%
	Total							26,4%
Jerricans +/-100% HDPE	30%	hazardous					0%	0%
	70%	non hazardous	50%	not recyclable			0%	0%
			50%	food		recyclable	95%	33,3%
	Total							33,3%
IBC			100%	reuse			95%	95%

Films *	44%	shrink					85%	37.4%
	56%	stretch					50%	28%
	Total							65.4%
EPS**						recyclable	25%	25%
Sacks							30%	30%
HDPE, LDPE, PP								
Pallets		pallets	96% reuse				40%	40%
Crates		crates	90-95% reuse				25%	25%

* Stretch and shrink films can not be recycled together. They can be easily identified and separated by hand by professionals.

** The weighted target was determined by EUMEPS (recycling rate 2001 for EU). It is accepted as the EPS recycling target without additional analysis because it influences slightly the recycling range of "other plastic packaging".

The achievable recycling rates considered for the industrial & commercial packaging waste case studies, taking into account the recycling limits, are summarised in Table 7:

Table 7 : achievable recycling rates for industrial packaging waste

		Best estimate	Range
Plastics	Palletisation films	65.4%	55-75%
	Others	31%	21-41%
	Total	46%	36-56%
Wood		60%	50-70%
Steel		85%	80-90%
Corrugated board		72%	64-80%
Glass		66%	50-83%
Others		0%	0%

The sources for those data are the following ones.

	Data Source	**Comments**
Plastics	Interview of EuPC Potential for post-user plastic waste recycling, Sofres-TNO, commissioned by APME, March 1998	The recycling rates determined in collaboration with EuPC were applied to the available amount in Western Europe.
Wood		40% are assumed to be used by household – 60% recycling for repair of pallets and making of particle board
Steel	Interview of APEAL	
Corrugated board	Interview of CEPI	
Glass	Interview of FEVE	In case of high amount, assumed to be mainly household packaging
Others	Assumption	Insufficient amount to be collected selectively

3.3.1.2 Reuse case study

For the reuse case study, the following systems are considered:

- Single-trip packaging system for glass and PET
- Reusable packaging system for glass and PET

For the reusable system, a baseline scenario is modelled as a function of 2 main influencing factors:

- Reuse rate of reusable primary pack = x times
- Distance travelled for the collection of reusable packaging = y km

The influence of reuse rate and distance are then investigated. Results are presented as a function of those factors. But no optimum target can be derived from the calculations because no market data was sought on the actual:

- transport distances
- number of uses of the refillable packaging

3.3.2 Model the internal costs

The internal costs considered in this study are defined as "the operational costs incurred by industry".

3.3.2.1 Recycling case studies

A "steady state" model is assumed (i.e. the costs of operating an existing successful system are considered). The analysis includes the capital costs required to develop the infrastructure necessary to achieve the defined recycling rate. These capital costs are considered only as a function of throughput of waste (i.e. they are allocated per tonne of waste managed). No consideration of the time at which these capital costs would be incurred by each Member State has been made. E.g. for an incineration plant, the cost per ton includes :

- the investment cost per ton : investment value / tons handled over the lifetime
- the financing cost per ton : present value of the interests paid in the future to finance the investment / tons handled over the lifetime

The total internal cost of each scenario is the sum of all costs minus the sum of all revenues. This is similar to the concept of "financing need" as considered in the TN Sofres report "Cost efficiency of Packaging Recovery Systems – The case of France, Germany, The Netherlands and the UK". Where the financing need is positive, recycling is not a self-supporting activity – intervention in the market is required to stimulate recycling. Where the financing need is negative, recycling is a potentially profitable activity, and under the right circumstances may occur without intervention in the market.

Internal costs have been determined for each specific detailed system. However, even where equivalent waste management practices are compared, internal costs can vary considerably between Member States, depending on a range of factors such as cost of living and geographical considerations (mountainous regions, islands, etc). Therefore the sensitivity analysis considers the influence of a variation of +/- 20% of the total internal costs on the determination of the optimum system. The size of the range is based on interviews with compliance schemes and industrials.

The internal costs applied in this study are summarised in **Annex 3: Internal cost data**.

Example: Internal cost calculation for PET Bottles scenarios See chapter 4.2.1.2

3.3.2.2 Reuse case studies

For the reuse case studies, the internal costs of reuse systems include the costs of raw material production and conversion, filling, distribution, collection, washing, and waste management of non-returned bottles (or single-trip bottles). The influence of reuse rate and distance on internal costs is investigated. The internal costs applied in this study are summarised in **Annex 3: Internal cost data**.

3.3.3 Model the external costs

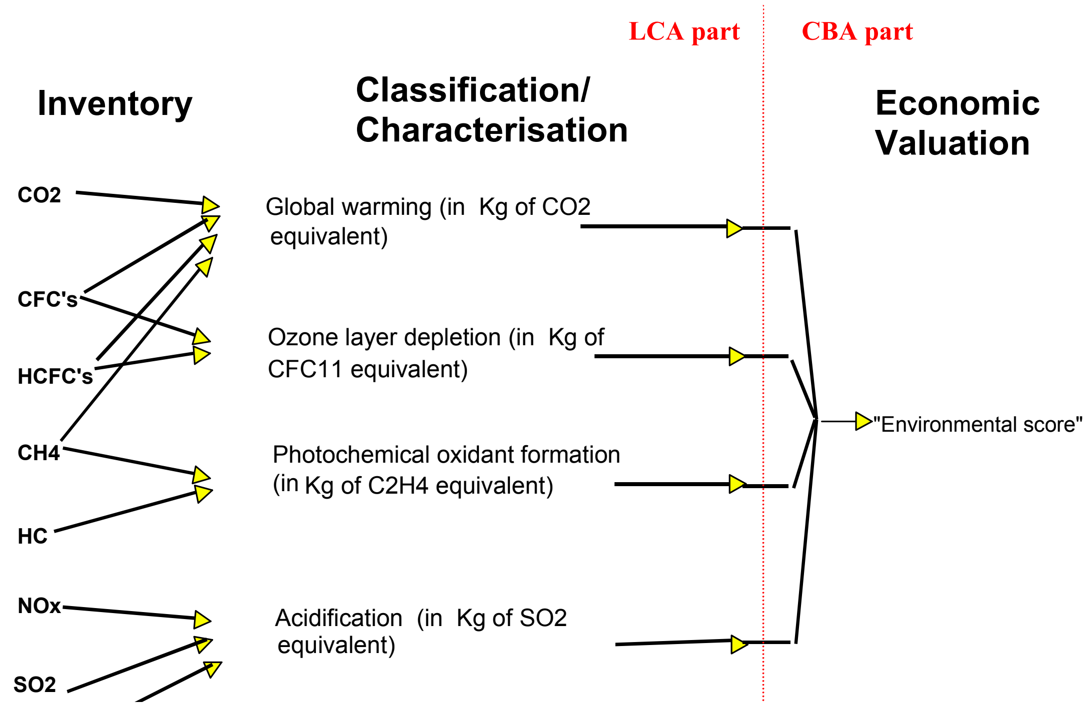
In this study, the environmental impacts of each scenario are modelled using an LCA approach.

First, the environmental inputs and outputs are modelled in line with the requirements of ISO 14040[5] and ISO14041[6], using the Pira International LCA model PEMS 4.7 (inventory analysis).

Each environmental input or output is then classified according to the environmental impacts to which it may contribute, and characterised according to its potential to contribute to that impact. (For the LCA part the ISO methodology is applied, i.e. no weighting. In a consecutive stage, the CBA methodology is applied, including monetisation[7] of environmental problems. This process is demonstrated in Figure 5.

[5] ISO14040 Environmental management - Life cycle assessment - Principles and framework
6 ISO14041 Environmental management - Life cycle assessment - Goal and scope definition and inventory analysis
[7] also called "economic valuation"

Figure 5 : Impact assessment in LCA



Finally, an economic valuation is applied to each environmental impact category. This allows the environmental impacts to be converted into a common monetary unit, which can then be summed to provide an estimate of the total external costs of the scenario. The sources of environmental data applied in this study are listed in **Annex 7: Environmental data sources**.

The methodology applied in this study considers the following impact categories (as listed in Table 8).

The following environmental impact categories and economic valuations are applied:

Table 8 : economic valuations

	Unit	Valuation
GWP (kg CO2 eq.)	€/kg CO2	0,01344
Ozone depletion (kg CFC 11 eq.)	€/kg CFC11	0,68
Acidification	€/kg H+	8,70
Toxicity Carcinogens (Cd equiv.)	€/kg Cadmium (carcinogenic effects only)	22
Toxicity Gaseous non carcinogens (SO2 equiv.)	€/kg SO2 from electricity production	1
Toxicity Metals non carcinogens (Pb equiv.)	€/kg Pb	62
Toxicity Particulates & aerosols (PM10 equiv.)	€/kg PM10 from electricity production	24
Smog (ethylene equiv.)	€/kg VOC	0,73
Black smoke (kg dust eq.)	€/kg smoke	0,66
Fertilisation	€/kg expressed as NO2 mass equivalents	-0,7
Traffic accidents (risk equiv.)	€/1000 km travelled on an average road	17
Traffic Congestion (car km equiv.)	€ per 1000 car km equivalents	86
Traffic Noise (car km equiv.)	€ per 1000 car km equivalents	3
Water Quality Eutrophication (P equiv.)	€/kg P	4,7
Disaminity (kg LF waste equiv.)	€/kg waste in landfill	0,037

The economic valuations applied in this study are principally based on damage cost estimates, derived from hedonic pricing methods or willingness-to-pay studies. A detailed summary of the sources and derivation of these economic valuations is provided in **Annex 4: Economic valuations applied – sources and derivation**.

3.3.3.1 Recycling case studies

Example: Calculation of externalities for PET bottles scenarios

See chapter 4.2.1.3

3.3.3.2 Reuse case studies

The externalities are determined for the base case, and investigated as a function of the reuse rate and collection distance.

3.3.4 Model gross employment created by each system

The EU has a special obligation to consider employment aspects in the development of policies under the Treaty of Amsterdam.

However, in neo-classical economics, no social cost is associated with unemployment. It is assumed that the economy is effectively fully employed. The labour market is fully flexible and unemployed labour will find employment elsewhere in the economy. Any unemployment is the result of transitional periods. The terms of labour employment contracts and the terms of unemployment benefits will reflect the presence of such periods. There will be no cost to society from the existence of a pool of transitionally unemployed workers. Therefore, CBA of environmental policies often deliberately excludes the direct and indirect employment effects.

However, market conditions are not perfect. Some Member States experience unemployment that is not due to a short-term transition in supply and demand of labour and skills, but due to a medium or long-term lack of employment opportunities. This unemployment has costs that should be considered. These costs include the economic burden of unemployment benefit, and the social welfare (health and well being) of the unemployed individuals and their family. Therefore a consideration of the costs and benefits of employment generated by some policies may be important.

However, quantifying the net employment created by recycling is not an easy task. Recycling will undoubtedly generate new employment in collection, sorting and reprocessing activities. Other jobs may be lost (in virgin material extraction and processing and MSW management) although obviously less due to the scale of the activities and the high automation value of the virgin material production systems. It needs to be underlined that a full evaluation of the employment effect of a policy measure can only be made after consideration of macroeconomic effects (e.g. crowding out effects). This is beyond the scope of this study. Even where this information could be derived, difficulties exist in determining an acceptable economic valuation for each job created, especially considering the variable quality of employment in this sector[8].

In this study, an attempt has been made to determine the employment created. Only the gross jobs of each scenario are quantified. The gross jobs are those involved in the collection and subsequent waste management processes (i.e. landfill & incinerator operation, sorting and reprocessing). The base data used to determine the gross jobs per scenario is presented in **Annex 5: Employment data –jobs for waste management activities**. This data has been sourced from Beture, interviews of compliance schemes and visits of recycling plants.

No economic valuation has been applied to the gross jobs in the base case. But the effect of economic valuation of net job creation on the cost-benefit balances has been tested in the sensitivity analysis. The information is considered cautiously in the interpretation of the results.

3.3.4.1 Recycling case studies

Example: Calculation of gross employment for PET bottles scenarios

See chapter 4.2.1.4

3.3.4.2 Reuse case studies

Only the gross jobs created by collection are considered.

3.3.5 Compile total social costs of each scenario

3.3.5.1 Recycling case studies

For each scenario, the total social cost is determined. The total social cost considered is the sum of the internal costs to industry and the total externality.

[8] for more detailed information see: "Employment effects of waste management policies", RPA for the European Commission, forthcoming in 2001

Example: Total social costs by scenario for PET bottles

See chapter 4.2.1.5

3.3.5.2 Reuse case studies

The total social cost is determined as a function of reuse rate and distance for collection.

3.3.6 Uncertainty / Sensitivity analysis of the CBA results

For each of the scenarios modelled, the main parameters that may affect the results are investigated. Two types of parameters are considered:

- Uncertainties arising from methodological choices, including but not limited to:
  - Energy model assumed
  - Offset energy production from incineration (average or marginal)
  - Valuations applied to externalities (a list of alternative economic valuations that may be applied is given in **Annex 4: Economic valuations applied – sources and derivation**)

- Uncertainties arising from scenario choices, including but not limited to:
  - Distances for kerbside collection rounds and bring schemes
  - Transport distances for delivery of sorted material to reprocessors
  - Offset virgin production and save ratio
  - Type of energy recovery from incineration and landfill (CH&P instead of power)
  - Alternative recovery options
  - Data used and data gaps

Example: Uncertainty and sensitivity analysis for PET bottle case study

See chapters 4.2.1.7 and 4.2.1.8

3.3.7 Interpretation

3.3.7.1 Recycling case studies

For each case study, the results are presented as ranges for the following:

- total external costs

- total internal costs
- total social costs (sum of external and internal costs)

The key parameters influencing the results are presented, and the limitations this may place on conclusions that can be drawn are discussed.

Example: Interpretation of results for PET bottles case study See chapter 4.2.1.6 and 4.2.1.9

3.3.7.2 Reuse case studies

For the reuse case studies, the results are considered in light of the influence of reuse rate and distance for collection.

3.4 Application of the CBA results to determine optimal recycling targets (step 4)

The aim of this step is to show how the results of the CBA case studies may be applied to determine possible recycling targets.

A combination of factors will determine the ability of a Member State to meet a specific recycling target. The following factors are considered in this analysis to determine recycling targets:

- the packaging mix of the Member State
- the proportion of population living in high and low population density areas in the Member State
- the proportion of landfill and incineration with energy recovery available in the Member State
- the proportion of companies producing small and large quantities of packaging waste (for commercial and industrial packaging applications only)

These factors are quantified for each Member State, so as to allow targets to be determined at a number of levels:

- aggregated global targets

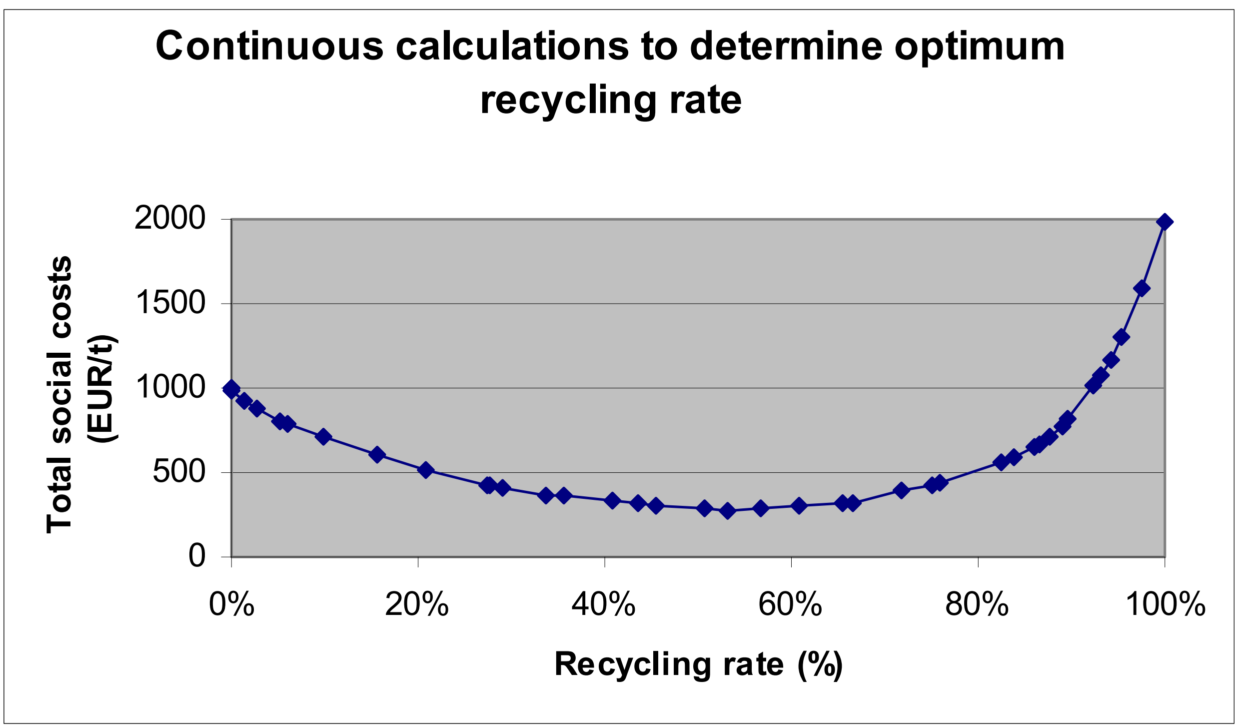
- Member State specific targets
- material specific targets

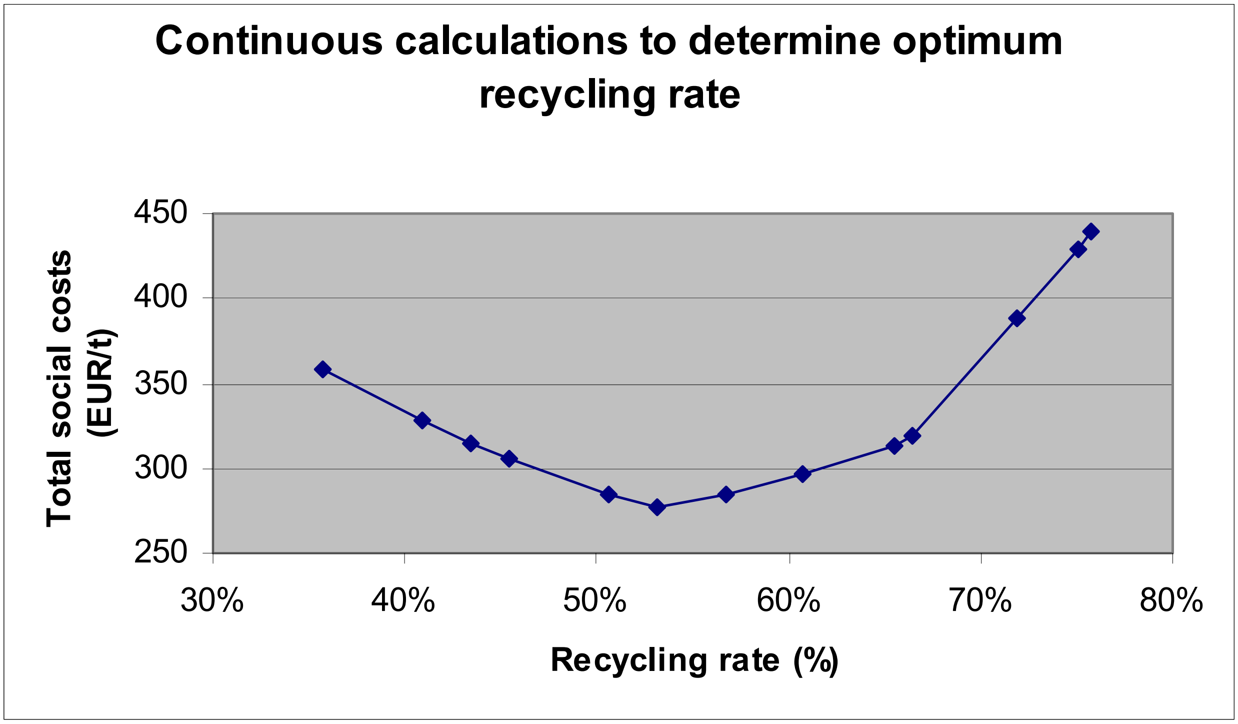
The process of applying the CBA results to determine the recycling targets is illustrated for household packaging by the sub-steps shown in Figure 6:

Note : The study did not assume that costs linearly increase with recycling rates. We basically assumed that a change in the recycling rate is mainly achieved by changing the fundaments of the systems, either :

- by changing the collection system (bring or kerbside selective collection),
- by adding other types of packaging that are collected selectively
- or by extending the collection to the less densely populated areas.

All those elements, which are the principal ways to modify the recycling rates, were taken into account. So the approach is very far from considering a linear relation between recycling cost and recycling rates. We used a sophisticated approach by taking those elements into account. The 2 next graphs show the evolution of the total cost when the recycling level of a specific material increases (the second graph is a focus of the first graph around the optimum point).



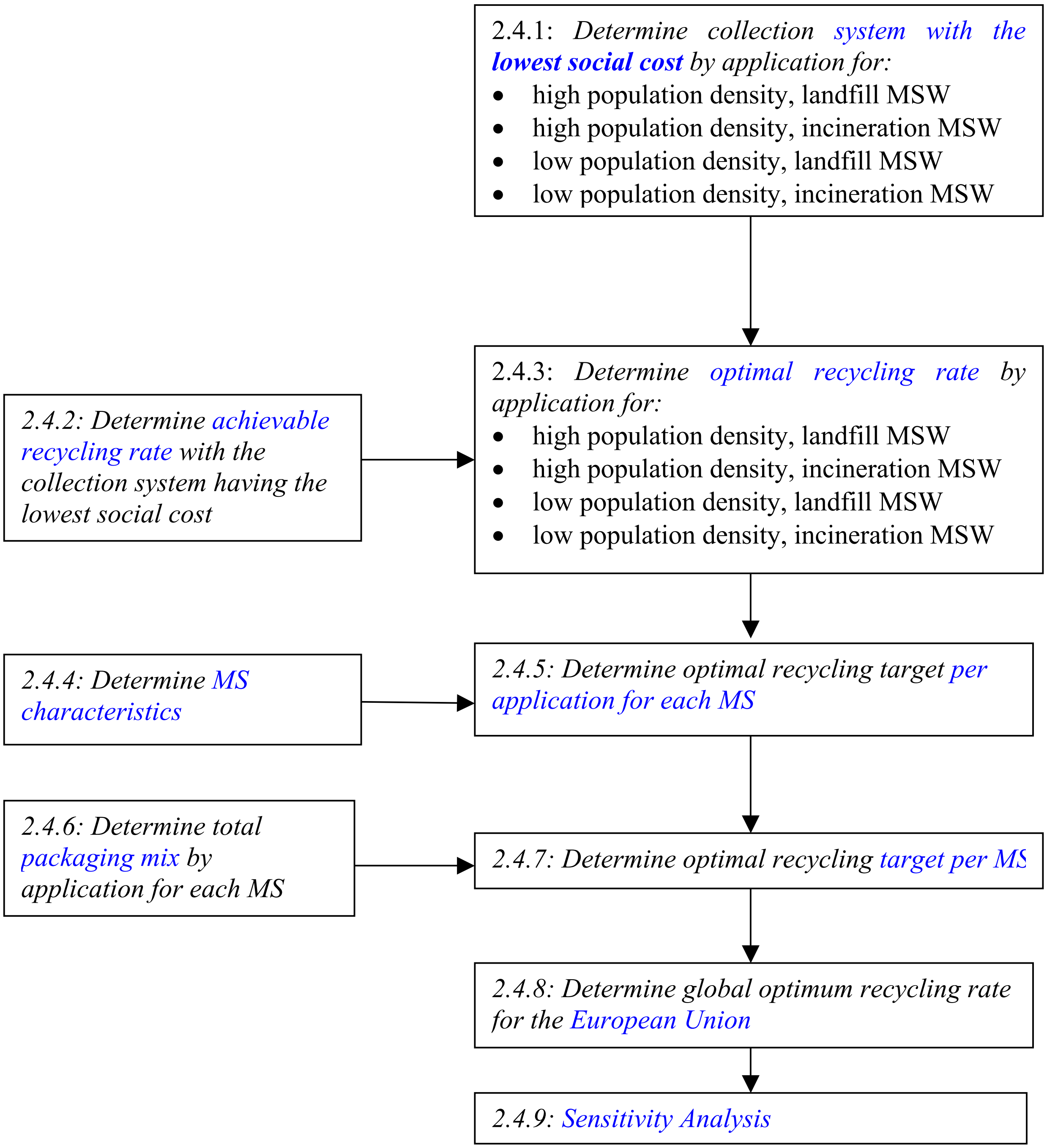


In order to determine the optimum recycling rate for a packaging material, the specific cost (EURO/t) due to the switch from a non selective to a selective collection has been calculated for :

- each application
- each type of population density (high / low)
- each type of MSW treatment method (incineration / landfill)

The optimum recycling rate is the one achieved when selective collection is applied in all cases where the specific cost is negative. In the graph above (based on fictive data) the optimum recycling rate is 53%.

Figure 6 : Application of CBA results to determine possible recycling targets for household packaging waste



3.4.1 Determine optimal recycling rate by application

For each household packaging application, the optimal recycling rate is determined for each of the following combinations of parameters:

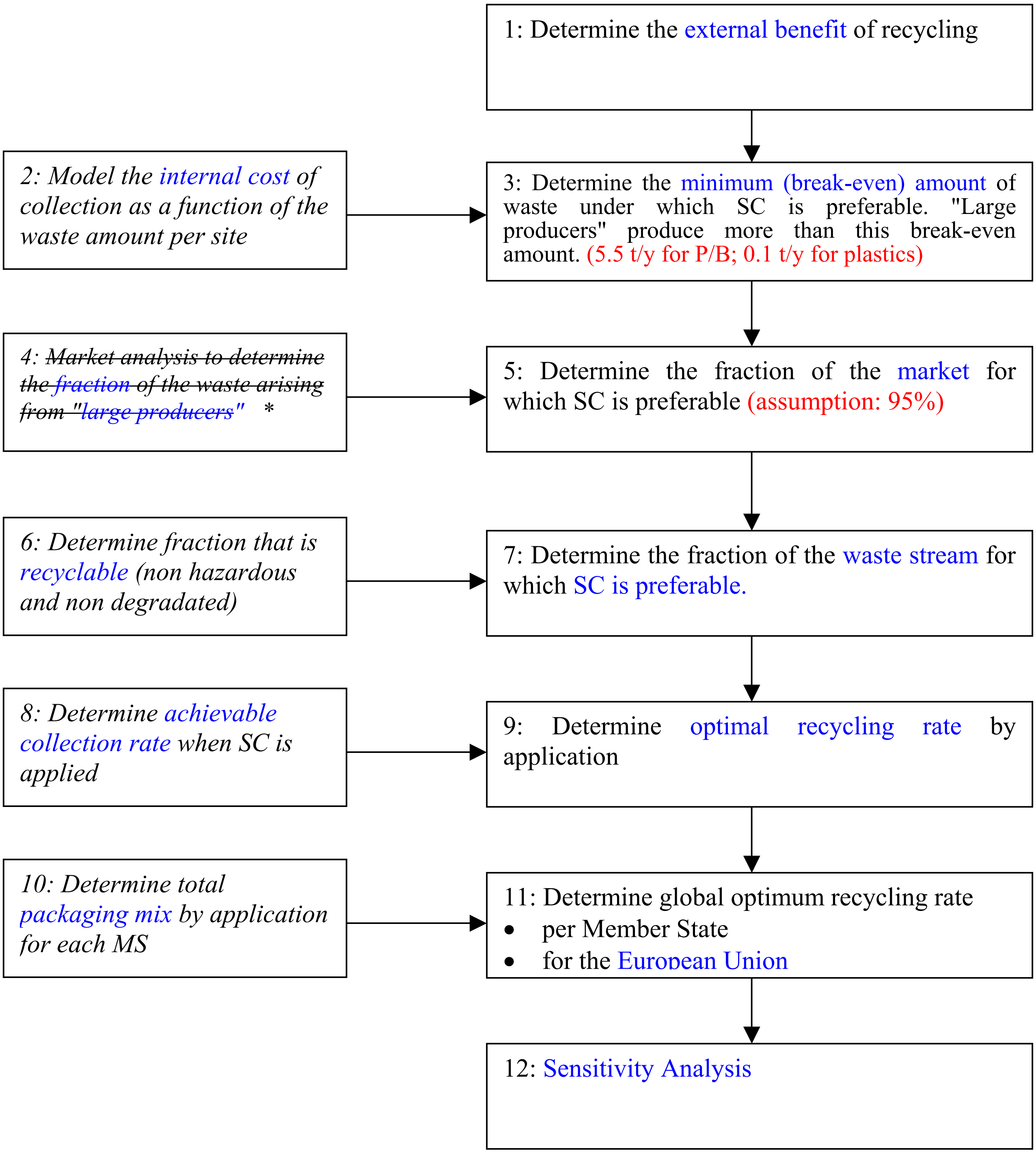
- High population density, with landfill as the alternative waste management option
- High population density, with incineration as the alternative waste management option
- Low population density, with landfill as the alternative waste management option
- Low population density, with incineration as the alternative waste management option

For each combination of parameters, the "optimal" recycling rate is considered to be the recycling rate achievable by the scenario modelled with the lowest total social cost.

Example: Determination of optimal recycling rate for PET bottles in function of the MS characteristics
See chapters 4.2.1.5 & 4.2.1.6

For industrial packaging application(s), the substeps are as follows.

Figure 7: Application of CBA results to determine possible recycling targets for industrial packaging waste



* strikethrough because note applied in practice

For each (group of) industrial packaging application(s), the industrial companies are classified according to the amount of packaging waste they produce. The internal and external costs and benefits are calculated for 3 systems :

- selective collection and recycling
- no selective collection and incineration
- no selective collection and landfill

The internal costs of the selective collection are considered as a function of the amount of packaging waste of the concerned material (cost of selective collection decreases when the amount of waste increases). The amount of packaging waste for which the total social cost of the selective collection system is equal to the total social cost of the (cheapest among the 2) non-selective collection system(s) is the **break-even** amount.

- Selective collection within companies which produce a "small" (i.e. smaller than the break-even) amount of packaging waste is considered not beneficial[9] and therefore the optimum recycling rate is 0%.
- Selective collection within companies which produce a "high" (i.e. more than the break-even) amount of packaging waste is considered beneficial and therefore should be applied. The optimum recycling rate is considered to be the recycling rate achievable with the selective collection.

The "optimum" recycling rate for the industrial packaging application is then equal to :
Percentage of the packaging waste arising in companies which produce a "high" amount of packaging waste multiplied by the *recycling rate achievable in companies who do make selective collection.*

The 3 key stages of the work are :

---

[9] i.e. the total social cost of selective collection + recycling is higher than the total social cost of non selective waste collection + incineration or landfill. ie the additional internal cost for selective collection exceeds the additional external benefits from recycling

- the determination of the break-even amount of packaging waste
- the determination of the fraction of the industrial packaging waste arising from the companies producing larger amount than the break-even amount and
- the determination of the recycling rate achieved when there is a selective collection

Note : as Step 3 showed that the break-even concerns a very low amount, Step 4 was skipped and replaced by the assumption that in 95% of the situation (percentage in amount of packaging waste) selective collection is preferable.

The optimum recycling rate is calculated according to 2 approaches :

- cost-benefit analysis : the break-even amount is the one for which the additional cost due to the selective collection equals the (environmental and job creation) benefits. An assumption needs further to be made on the fraction of the packaging waste arising from large packaging waste production sites
- market approach : for Member States where the incineration/landfill tax is about the same level as the (external) benefits of the selective collection, the external benefits are considered as fully internalised. Therefore, assuming the market is efficient, the current recycling rate is the optimum one. This second approach is used to check and calibrate the first model.

3.4.2 Determine Member State Characteristics

For each Member State the following characteristics are determined:

- **Population mix by density and alternative waste management option**

This data is applied in the calculation of the optimal recycling target for household packaging applications.

The population of each Member State is classified into 4 categories:

- High population density (> 200 inhabitants/km^2) served by landfill
- High population density (> 200 inhabitants/km^2) served by incineration
- Low population density (< 200 inhabitants/km^2) served by landfill
- Low population density (< 200 inhabitants/km^2) served by incineration

To achieve this, the % of the population living in high and low population density areas is determined for each Member State, based on data available at I-Mage (Belgian consulting company working for the EC) and checked by local consulting companies[10]. The proportion of the population living in high and low population density areas is shown in Table 9.

Table 9 :Population density distribution by Member State (estimation for 2000)

Population density		AUT	B	DK	FIN	F	D	GK	IRL	I	L	NL	P	SP	SE	UK
Low density	% pop	47%	14%	66%	58%	34%	26%	41%	50%	28%	34%	13%	40%	55%	73%	16%
High density	% pop	53%	86%	34%	42%	66%	74%	59%	50%	72%	66%	87%	60%	45%	27%	84%

The percentage of municipal solid waste sent to landfill or incineration with energy recovery in each Member State was determined by local consulting companies. The distribution is determined based on data and forecasts for 2000. Otherwise data related to previous years (1998-1999) are used. The proportion of landfill to incineration is summarized in Table 10.

[10] A network of consulting company specialised in environmental matters support the data search and checked the local data

Table 10 :Percentage split of municipal solid waste management (estimation for 2000)

Member State	Waste fraction incinerated	Waste fraction landfilled
Austria	30%	70%
Belgium	50%	50%
Denmark	100%	0%
Finland	5%	95%
France	47%	53%
Germany	40%	60%
Greece	0%	100%
Ireland	3%	97%
Italy	8%	92%
Luxembourg	70%	30%
The Netherlands	50%	50%
Portugal	9%	91%
Spain	7%	93%
Sweden	65%	35%
United Kingdom	7%	93%

Sources :

- Eco-Emballages 1999
- Interviews of stakeholders 2000
- Network of consultants.

Subsequently, the population is classified according to both the population mix and the national MSW treat option. The results of this are presented in Table 11.

Table 11 : Population mix as a function of density and national MSW treatment (estimation for 2000)

Pop Density	MSW system	AUT	B	DK	FIN	F	D	GR	IRL	I	L	NL	P	SP	SE	UK
Low	Landfill	47%	7%	0%	58%	22%	16%	41%	49%	26%	10%	6%	36%	51%	26%	15%
	Incin.	0%	7%	66%	0%	8%	10%	0%	2%	2%	24%	6%	4%	4%	47%	1%
High	Landfill	37%	43%	0%	40%	32%	44%	59%	48%	66%	20%	44%	55%	42%	9%	78%
	Incin.	16%	43%	34%	2%	39%	30%	0%	1%	6%	46%	44%	5%	3%	18%	6%

It should be noted that this allocation assumes that the proportion of landfill to incineration is the same in high and low population density areas. In reality, there may be localised variations that have been addressed in this study as far as data were available (e.g. for Austria, France, Finland). The situation in 2006 is considered in the sensitivity analysis.

3.4.3 Determine total packaging mix by application for each Member State

It is assumed that the optimal recycling rate in a Member State is a function of the packaging mix in that Member State, as some packaging materials/applications will be easier to recycle than others. Therefore the packaging mix in each Member State must be determined in order to calculate the Member State's optimal recycling target. In this analysis, the packaging mix for 2000 is considered as the baseline. No forecast for the year 2005 is considered, though the effect of changes in the packaging mix on the optimal recycling rates are investigated in the sensitivity analysis.

In this analysis, data on the Member State packaging mix has been derived from a number of sources:

- Data provided by the national compliance schemes
- Member State's official declarations
- Additional input from local consultants where possible

The detailed packaging mix of each Member State as determined for this analysis is given in **Annex 6: Packaging mix by Member State**.

3.4.4 Determine optimal recycling target per application for each Member State

The optimal recycling rate per application for each Member State is calculated by combining the optimum recycling rate per application with the Member State characteristics.

Example: PET bottles optimal recycling rate

	EU PET packaging amount		1 501	kt		
	Percentage of population living in areas where population density is L/H and waste are I/L					
	Low		High			
	landfill	Inc.	landfill	Inc.	amount to be recycled	Target range
	27%	12%	41%	20%		
	Achievable recycling rates					
Min targets	70%	35%	59%	59%	887	59%
Max target	80%	80%	69%	69%	1 101	73%

In the above table the minimum target (i.e. minimum achievable recycling rate when the collection systems with the lowest total social cost are applied) is 59%, i.e. 887 kt/1501 kt or 59% = (27%*70%) + (12%*35%) + (41%*59%) + (20%*59%).

3.4.5 Determine the optimal recycling rate for each Member State

By combining the optimal recycling rate for each packaging material/application by Member State with the packaging mix by Member State, the overall recycling target for that Member State is determined. The overall recycling targeted is a weighted average of the individual packaging material/application targets.

3.4.6 Determine global packaging recycling for the whole EU

The optimal recycling rate of all packaging waste for the whole EU is the weighted average of the optimal recycling rates of the individual Member States. The weighting factor is the annual amount of packaging waste.

3.4.7 Sensitivity analysis

The sensitivity of the recycling targets to changes in the packaging mix is investigated. Forecast for packaging mix in 2006 was investigated. Optimum recycling ranges per application were applied to this new packaging mix, in order to determine the influence of the packaging mix on the global results.

3.5 Recommendations and Conclusions (step 5)

Based on the results of the analysis, the consultants make conclusions and recommendations on:

- The existing recycling and recovery rates achieved by the Member States
- The possible options for implementing higher recycling targets
- The possible range of the recycling targets
- The key factors that influence the costs and benefits of reuse

4 RESULTS

4.1 Evaluation of the current situation

4.1.1 Current performance of Member States

As explained in the description of the methodology (see chapter 3.1.1) the current performances of the Member States were investigated.

The methodology and the problems encountered are described in **Annex 8: Current performance of Member States**.

Data of 1999 are presented in Table 12. Data for 1997 and 1998 are presented in annex 8 bis.

The main conclusions are:

- Most data were found for 1997 and 1998
- Exact data on the amount of waste, packaging waste and recycling are hard to get;
- Data on the amount of waste, packaging waste and recycling are not comparable;
- More reliable data are/will be available for 1998 and especially 1999 thanks to the larger experience and the improvement of the calculation methods.

Table 12 : Performance of the Member States in 1997

Total HH + industrial										
Material	Glass	Plastic	Paper and board	Metals	Al	Steel	composites	Wood	Other	Total
Application										
1997										
Waste										
AUT	260	180	666	85			28	50		1269
BE	310	208	530	121			17	142	29	1356
DK	202	183	463	58				61	4	971
FI	52	90	244	31						417
FR	3296	1571	3611	622			290	1679		11069
DE	3750	1502	5448	1121	87	1034		1892	17	13731
GK										1456
IE										452
IT	2248	1777	3246	487				1802		9560
LU	17	7	11	3			1		1	80
NL	469	611	1449	216				0		2745
PO										1050
SP	1398	1215	2255	340					671	5879
SE	177	150	527	70						924
UK	1787	1356	3035	809	112	697		749	18	7755
EU										
Recycled										
AUT	199	36	500	29			8	7		779
BE	217	53	411	85			5	75		846
DK	124	11	219	2						357
FI	24	9	136	2						171
FR	1388	102	2276	331				300		4397
DE	2797	675	3193	915				1040		8621
GK										180
IE										80
IT	750	164	1170	25				700		2809
LU										
NL	354	76	941	145						1516
PO										32
SP	522	65	1242	76					60	1966
SE	134	21	348	32						535
UK	441	100	1609	211	27	184				2361
EU										

Legend:

data EC -MS reports 1997

data report PWC review data MS 1997

data valorlux : chiffres cléfs only HH

data PWC The facts a European cost/benefit analysis 1998

4.1.2 Critical factors limiting recycling and reuse

The critical factors identified in this section are taken into account in the calculations and the hypothesis taken for packaging applications when no CBA is performed.

Recycling difficulties can be classified according to technical, economic and marketing constraints. Marketing constraints can be avoided by specific marketing actions: they mainly depend on the willingness of the industries.

On the other hand technical and economical constraints are more difficult – or impossible up to now - to overcome. Technical constraints require R&D investments or increase of collecting, sorting and/or treatment capacities. Economic constraints are very difficult to control: e.g.: market prices, internal market barriers.

In **Annex 9: Critical factors limiting recycling and reuse**, the different material are investigated.

Table 13 shows the identified recycling constraints per material. They are classified in factors which are reasonable reasons to limit recycling and factors which may be valid points but are not really a reason to limit recycling.

Table 13 : Summary of the recycling difficulties

Recycling difficulties	Glass	Plastics	Paper/board	Metals	Composites
Capacity	X		(X)		
Output market / market price	X	X			
contamination	X	X	X	(X)	
imbalance supply-demand	X		X		
Insufficient amount of waste		X		(X)	X
Recycling lifetime			X		
Nature of waste (too thin,…)		X	X	X	X
Recycling costs		X			
Factors which are not really a reason to limit recycling					
Noise	X				
Human wound	X				
Insufficient maintenance	X				
Disposers participation	X	X	X	X	X
Colour, odour		X			
Resistance to the use of recyclate		X			

The critical factors identified in this section are taken into account in the calculations and the hypothesis taken for packaging applications when no CBA is performed.

For reuse processes, as for recycling, it is possible to distinguish between technical and economical constraints. The third kind of constraints concern consumer convenience.

These constraints are discussed in **Annex 9: Critical factors limiting recycling and reuse**.

4.2 Results of Case study CBAs

In this section, the full set of calculations and results for PET beverage bottles are explained, including a detailed presentation of the sensitivity analysis. For other cases studies, only the main results and conclusions and the implications of the sensitivity analysis are presented.

4.2.1 PET bottles from household sources

4.2.1.1 Scenarios considered

Table 14 summarises the parameters considered for the baseline scenarios modelled.

Table 14 : Scenarios considered for PET beverage bottles

	Population density	Selective collection scheme	Recycling rate achieved	MSW Waste management option
Scenario 1	Low	None	0%	Landfill
Scenario 2	Low	None	0%	Incineration
Scenario 3	Low	Separate kerbside collection	70-80%	Landfill
Scenario 4	Low	Separate kerbside collection	70-80%	Incineration
Scenario 5	Low	Bring scheme	35-45%	Landfill
Scenario 6	Low	Bring scheme	35-45%	Incineration
Scenario 7	High	None	0%	Landfill
Scenario 8	High	None	0%	Incineration
Scenario 9	High	Separate kerbside collection	59-69%	Landfill
Scenario 10	High	Separate kerbside collection	59-69%	Incineration
Scenario 11	High	Bring scheme	22-32%	Landfill
Scenario 12	High	Bring scheme	22-32%	Incineration

4.2.1.2 Calculation of internal costs

The internal costs of each possible waste management option are calculated. To achieve this, a number of allocations are applied:

- Allocation of MSW collection costs proportionally to the compressed density in the collection truck
- Allocation of sorting costs proportionally to the density
- Allocation of fixed incineration costs proportionally to calorific value, necessary combustion air (mainly), ash content, steel content, Al content, depending on the part of the facilities

  Allocation of variable incineration costs proportionally to variable parameters (a.o. necessary combustion air, ash content, steel content, Al content)

  For further details about incineration costs, see **Annex 2: Incineration and landfill models**.
- Allocation of landfill costs proportionally to the crushed waste density in landfill

Costs for Landfilling 1 tonne PET bottles

	Collection costs (Euro per tonne of PET bottles)	Landfill costs (Euro per tonne of PET bottles)	Total internal costs per tonne PET bottles
High population density	294	140	**434**
Low population density	228	140	**368**

Costs for Incineration of 1 tonne PET bottles

	Collection costs (Euro per tonne of PET bottles)	Incineration – fixed costs (Euro per tonne of PET bottles)	Incineration – variable costs (Euro per tonne of PET bottles)	Total internal costs per tonne PET bottles
High population density	294	161	-63	**392**
Low population density	228	161	-63	**326**

Costs for Recycling 1 tonne of PET bottles via separate kerbside collection

	Collection costs (Euro per tonne of PET bottles recycled)	Sorting costs (Euro per tonne of PET bottles recycled)	Transport from sorting plant to reprocessor (Euro per tonne of PET bottles recycled)	Reprocessing cost (Euro per tonne of output)	Revenue received for reprocessed material	Total internal cost per tonne PET bottles recycled
High population density	255	474	46	332	-540	**566**
Low population density	306	474	46	332	-540	**618**

Costs for Recycling 1 tonne PET bottles via bring bank collection

	Transport costs from bring bank to sorting plant (Euro per tonne of PET bottles recycled)	Sorting costs (Euro per tonne of PET bottles recycled)	Transport from sorting plant to reprocessor (Euro per tonne of PET bottles recycled)	Reprocessing cost (Euro per tonne of output)	Revenue received for reprocessed material	Total internal cost per tonne PET bottles recycled
High population density	196	474	46	332	-540	**508**
Low population density	242	474	46	332	-540	**553**

The costs per tonne for each waste treatment option are combined to give the cost per tonne for each scenario modelled. For example, Scenario 3 considers low population density, in which 70-80% of the PET bottles are recycled via separate kerbside collection, with the remaining 20-30% going to landfill. Thus, the cost per tonne for Scenario 3 can be calculated:

Scenario 3 cost per tonne = (0.7 * 618) + (0.3 * 368) to (0.8 * 618) + (0.2 * 368)
= 542 – 567 Euro per tonne

4.2.1.3 Calculation of externalities

The environmental models for each option were constructed using Pira International's LCI/LCIA software PEMS. The life cycle inventory is then compiled.

The environmental impacts associated with the inventory data set are then calculated. To achieve this, the inventory data are characterised according to the potential impact categories that they contribute to, and then multiplied by classification values. Finally, the impact assessment data is multiplied by the economic valuations (as listed in **Annex 4: Economic valuations applied – sources and derivation**) to achieve the external cost of each impact category.

For example, if we consider only the global warming impact category, the following results are achieved for PET bottles scenario 3:

Table 15 : Calculation of GWP externality for 1 tonne PET bottles to landfill, low population density

Inventory data	Emissions (kg of emission per tonne PET landfilled)			Classification factor	Results of characterisation (CO2 Equiv.)			Economic valuation (Euro per kg CO2 Equiv)	Externality (Euros)		
carbon tetrachloride	0.0	to	0.0	-225	0.0	to	0.0				
CFC (unspecified)	0.0	to	0.0	1320	0.0	to	0.0				
CFC-11	0.0	to	0.0	1320	0.0	to	0.0				
CO2 (non renewable)	-1479.4	to	-1693.9	1	-1479.4	to	-1693.9				
CO2 (renewable)	0.0	to	0.0	1	0.0	to	0.0				
CO2 (unspecified)	34.5	to	38.5	1	34.5	to	38.5				
dichloromethane	0.0	to	0.0	9	0.0	to	0.0				
haloginated HC (unspecified)	0.0	to	0.0	4	0.0	to	0.0				
halon -1301	0.0	to	0.0	-49750	-0.5	to	-0.5				
halons (unspecified)	0.0	to	0.0	-49750	0.0	to	0.0				
HCFC (unspecified)	0.0	to	0.0	1350	0.0	to	0.0				
HCFC-22	0.0	to	0.0	1350	0.0	to	0.0				
hexafluoroethane	0.0	to	0.0	9200	0.0	to	0.0				
HFC (unspecified)	0.0	to	0.0	1000	0.0	to	0.0				
methane	0.2	to	0.2	21	4.5	to	5.0				
N2O	0.0	to	0.0	310	4.0	to	4.5				
tetrafluoromethane	0.0	to	0.0	6500	0.0	to	0.1				
tetrafluroethylene	0.0	to	0.0	1300	0.0	to	0.0				
trichloroethane	0.0	to	0.0	-1525	0.0	to	0.0				
trichloromethane	0.0	to	0.0	4	0.0	to	0.0				
					-1436.8		-1646.4	0.01344	-19.31116	to	-22.12759

For each scenario, the external cost of all impact categories is summed to determine the total external cost. The total external cost for PET bottles scenario 3 are presented in Table 16

Table 16 : Total externalities for PET bottles, Scenario 3

Externalities	Euro per tonne		
GWP (kg CO2 eq.)	-19.3	to	-22.1
Ozone depletion (kg CFC 11 eq.)	0.0	to	0.0
Acidification (Acid equiv.)	-6.9	to	-7.9
Toxicity Carcinogens (Cd equiv)	0.0	to	0.0
Toxicity Gaseous (SO2 equiv.)	-24.8	to	-28.4
Toxicity Metals non carcinogens (Pb equiv.)	-5.4	to	-6.2
Toxicity Particulates & aerosols (PM10 equiv)	-164.9	to	-189.8
Toxicity Smog (ethylene equiv.)	-35.7	to	-40.9
Black smoke (kg dust eq.)	-16.5	to	-18.9
Fertilisation	9.2	to	10.5
Traffic accidents (risk equiv.)	0.9	to	1.0
Traffic Congestion (car km equiv.)	5.0	to	5.7
Traffic Noise (car km equiv.)	2.8	to	3.1
Water Quality Eutrophication (P equiv.)	-0.8	to	-0.9
Disaminity (kg LF waste equiv.)	11.1	to	7.4
TOTAL EXTERNALITIES	**-245.5**	**to**	**-287.4**

4.2.1.4 Calculation of Employment

The gross employment is determined for each waste management option. This is presented in the tables below.

Gross Employment, landfilling of PET bottles (jobs per 1000 tonne per annum)

	Collection	Landfill management / operation	Total
High population density	1.2	0.1	1.3
Low population density	1.15	0.1	1.25

Gross Employment , incineration of PET bottles (jobs per 1000 tonne per annum)

	Collection	Incinerator management / operation	Total
High population density	1.2	0.27	1.47
Low population density	1.15	0.27	1.42

Gross Employment , kerbside collection and sorting of PET bottles

Jobs per 1000 tonne per annum	Collection	Sorting	Transport from sorting to reprocessing	Total
High population density	14.7	0.71	0.19	15.6
Low population density	17.7	0.71	0.19	18.6

Gross Employment , bring scheme collection and sorting of PET bottles

Jobs per 1000 tonne per annum	Transport, bring bank to sorting	Sorting	Transport from sorting to reprocessing	Total
High population density	3.2	0.71	0.19	4.1
Low population density	3.8	0.71	0.19	4.7

The total gross jobs for each scenario modelled can then be calculated. For example, Scenario 3 considers low population density, in which 70-80% of the PET bottles are recycled via separate kerbside collection, with the remaining 20-30% going to landfill. Thus, the gross employment per tonne for Scenario 3 can be calculated :

Scenario 3 jobs per 1000 tonne = (0.7 * 18.6) + (0.3 * 1.25) to (0.8 * 18.6) + (0.2 * 1.25)

= 13.4 – 15.13 jobs per 1000 tonne per annum (or 14.27 jobs per 1000 tonne per annum if the median is considered).

The external economic value for these jobs is then calculated by applying the economic valuation for employment (2945 Euro per job per annum, as described in **Annex 4: Economic valuations applied – sources and derivation**). Thus, for Scenario 3 the external economic value is 14.27/1000*2495 = 42.01 Euro per tonne of waste PET bottles.

4.2.1.5 Compile total social costs - Results of the cost benefit analysis

Table 17 : Internal costs, external costs and total social costs (low pop. density)

Collection method	**N/A**	**N/A**	**Separate Kerbside collection**	**Separate kerbside collection**	**Bring scheme**	**Bring scheme**
Recycling rate	**0.0**	**0.0**	**70-80%**	**70-80%**	**35-45%**	**35-45%**
Residual waste management option	**Landfill**	**Incineration**	**Landfill**	**Incineration**	**Landfill**	**Incineration**
Exeternalities						
GWP (kg CO2 eq.)	0.4	19.2	-19.3 to -22.1	-13.7 to -18.4	-9.5 to -12.3	2.8 to -1.9
Ozone depletion (kg CFC 11 eq.)	0.0	0.0	0.0 to 0.0	0.0 to 0.0	0.0 to 0.0	0.0 to 0.0
Acidification (Acid equiv.)	0.0	-1.2	-6.9 to -7.9	-7.3 to -8.1	-3.4 to -4.4	-4.2 to -5.1
Toxicity Carcinogens (Cd equiv)	0.0	-0.1	0.0 to 0.0	0.0 to 0.0	0.0 to 0.0	0.0 to 0.0
Toxicity Gaseous (SO2 equiv.)	0.1	-4.1	-24.8 to -28.4	-26.1 to -29.3	-12.0 to -15.4	-14.7 to -17.8
Toxicity Metals non carcinogens (Pb equiv.)	0.1	-0.5	-5.4 to -6.2	-5.6 to -6.3	-2.6 to -3.4	-3.0 to -3.7
Toxicity Particulates & aerosols (PM10 equiv)	9.6	-44.6	-164.9 to -189.8	-181.2 to -200.7	-83.4 to -110.0	-118.6 to -139.8
Toxicity Smog (ethylene equiv.)	0.3	-0.8	-35.7 to -40.9	-36.1 to -41.1	-17.7 to -22.9	-18.4 to -23.5
Black smoke (kg dust eq.)	0.2	-3.9	-16.5 to -18.9	-17.8 to -19.7	-8.1 to -10.5	-10.8 to -12.7
Fertilisation	-0.1	0.4	9.2 to 10.5	9.4 to 10.6	4.5 to 5.9	4.9 to 6.2
Traffic accidents (risk equiv.)	0.1	0.1	0.9 to 1.0	0.9 to 1.0	2.4 to 3.0	2.4 to 3.0
Traffic Congestion (car km equiv.)	0.1	0.1	5.0 to 5.7	5.0 to 5.7	2.6 to 3.3	2.6 to 3.3
Traffic Noise (car km equiv.)	0.4	0.4	2.8 to 3.1	2.8 to 3.1	1.3 to 1.5	1.3 to 1.5
Water Quality Eutrophication (P equiv.)	0.0	-0.1	-0.8 to -0.9	-0.8 to -0.9	-0.4 to -0.5	-0.4 to -0.5
Disaminity (kg LF waste equiv.)	37.0	12.0	11.1 to 7.4	3.6 to 2.4	24.1 to 20.4	7.8 to 6.6
TOTAL EXTERNALITIES	**48.2**	**-22.9**	**-245.5 to -287.4**	**-266.8 to -301.6**	**-102.3 to -145.3**	**-148.5 to -184.4**
INTERNAL COSTS	**368.0**	**326.0**	**542.3 to 567.2**	**529.7 to 558.8**	**432.8 to 451.3**	**405.5 to 428.2**
TOTAL SOCIAL COSTS	**416.2**	**303.1**	**296.8 to 279.8**	**262.9 to 257.2**	**330.5 to 306.0**	**256.9 to 243.7**

Graph 1 : Total social costs (low population density)

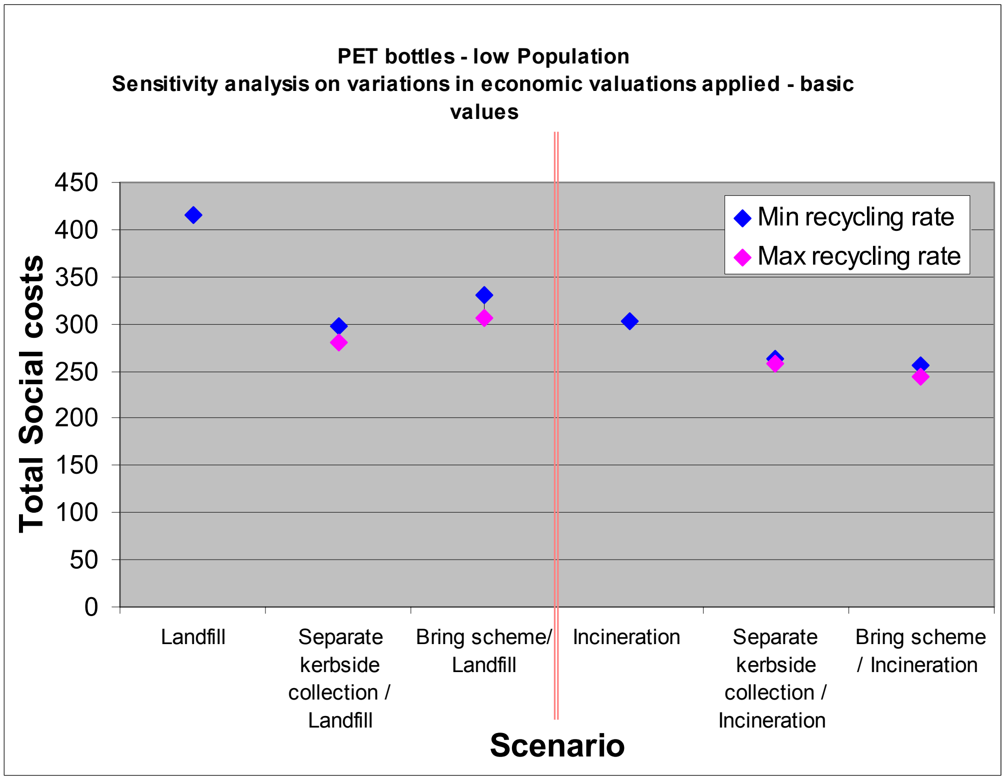
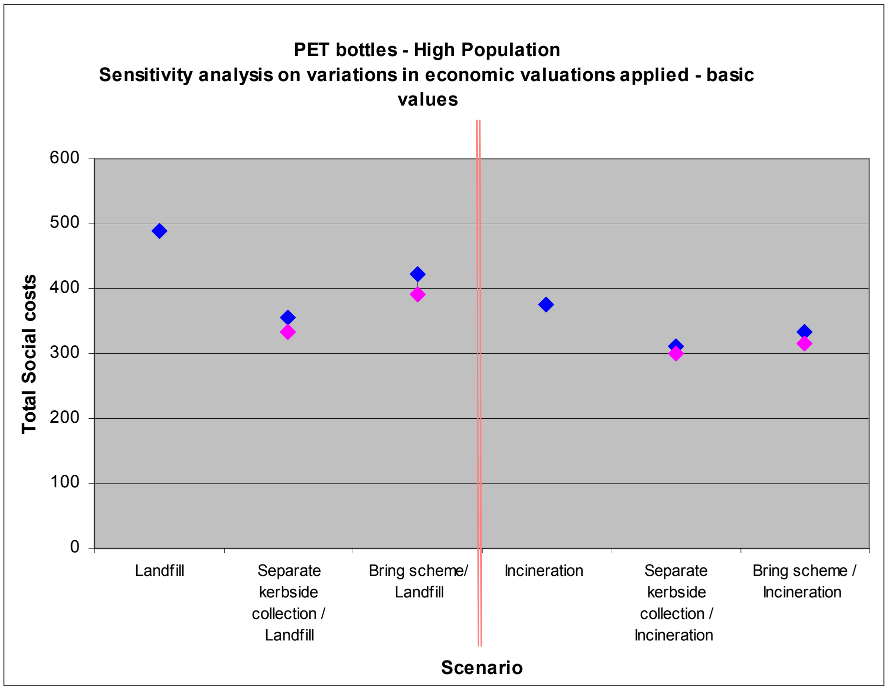


Table 18 : Internal costs, external costs and total social costs (high pop. density)

Collection method	N/A	N/A	Separate Kerbside collection			Separate kerbside collection			Bring scheme			Bring scheme		
Recycling rate	**0.0**	**0.0**	**59-69%**			**59-69%**			**22-32%**			**22-32%**		
Residual waste management option	**Landfill**	**Incineration**	**Landfill**			**Incineration**			**Landfill**			**Incineration**		
Exeternalities														
GWP (kg CO2 eq.)	0.3	19.1	-15.9	to	-18.7	-8.2	to	-12.8	-6.2	to	-9.1	8.5	to	3.7
Ozone depletion (kg CFC 11 eq.)	0.0	0.0	0.0	to	0.0	0.0	to	0.0	0.0	to	0.0	0.0	to	0.0
Acidification (Acid equiv.)	0.0	-1.2	-5.5	to	-6.4	-6.0	to	-6.8	-2.2	to	-3.1	-3.1	to	-4.0
Toxicity Carcinogens (Cd equiv)	0.0	-0.1	0.0	to	0.0	0.0	to	0.0	0.0	to	0.0	0.0	to	0.0
Toxicity Gaseous (SO2 equiv.)	0.1	-4.1	-19.8	to	-23.2	-21.5	to	-24.5	-7.7	to	-11.2	-11.0	to	-14.1
Toxicity Metals non carcinogens (Pb equiv.)	0.1	-0.5	-4.3	to	-5.1	-4.5	to	-5.2	-1.6	to	-2.4	-2.1	to	-2.8
Toxicity Particulates & aerosols (PM10 equiv)	8.3	-45.9	-136.3	to	-160.8	-158.5	to	-177.6	-52.6	to	-80.2	-94.8	to	-117.1
Toxicity Smog (ethylene equiv.)	0.2	-0.9	-28.7	to	-33.6	-29.1	to	-33.9	-11.2	to	-16.4	-12.1	to	-17.2
Black smoke (kg dust eq.)	0.2	-3.9	-13.2	to	-15.5	-14.9	to	-16.8	-5.1	to	-7.5	-8.3	to	-10.3
Fertilisation	-0.1	0.5	7.4	to	8.7	7.7	to	8.9	2.9	to	4.3	3.3	to	4.6
Traffic accidents (risk equiv.)	0.2	0.2	1.0	to	1.1	1.0	to	1.1	0.8	to	1.1	0.8	to	1.1
Traffic Congestion (car km equiv.)	8.2	8.2	44.4	to	50.5	44.4	to	50.5	25.4	to	33.3	25.5	to	33.3
Traffic Noise (car km equiv.)	0.2	0.2	1.1	to	1.3	1.1	to	1.3	0.4	to	0.6	0.4	to	0.6
Water Quality Eutrophication (P equiv.)	0.0	-0.1	-0.6	to	-0.7	-0.7	to	-0.7	-0.2	to	-0.4	-0.3	to	-0.4
Disaminity (kg LF waste equiv.)	37.0	12.0	15.2	to	11.5	4.9	to	3.7	28.9	to	25.2	9.4	to	8.2
TOTAL EXTERNALITIES	**54.6**	**-16.5**	**-155.3**	**to**	**-190.9**	**-184.4**	**to**	**-212.9**	**-28.4**	**to**	**-66.1**	**-83.8**	**to**	**-114.4**
INTERNAL COSTS	**434.0**	**392.0**	**511.9**	**to**	**525.1**	**494.7**	**to**	**512.1**	**450.3**	**to**	**457.7**	**417.5**	**to**	**429.1**
TOTAL SOCIAL COSTS	**488.6**	**375.5**	**356.6**	**to**	**334.2**	**310.2**	**to**	**299.2**	**421.9**	**to**	**391.6**	**333.7**	**to**	**314.7**

Graph 2 : Total social costs (high population density)



4.2.1.6 Initial conclusions

For low population density, where landfill is the MSW treatment option the main conclusions are:

- Landfilling is the preferred option from an internal cost perspective
- When total social costs are considered **separate kerbside collection** achieving a recycling rate of 70-80% is the optimal solution of the options considered. This is due to the environmental credit achieved by avoided production of virgin bottle grade PET. The main benefit is associated with avoided emissions of particulates and aerosols.

For low population density, where incineration is the MSW treatment option the main conclusions are:

- Incineration is the preferred option from an internal cost perspective
- When total social costs are considered a **bring scheme** achieving a recycling rate of 35-45% is the optimal solution of the options considered. This is due to the environmental credit achieved by avoided production of virgin bottle grade PET. The main benefit is associated with avoided emissions of particulates and aerosols.

For high population density, where landfill is the MSW treatment option the main conclusions are:

- Landfilling is the preferred option from an internal cost perspective
- When total social costs are considered **separate kerbside collection** achieving a recycling rate of 59-69% is the optimal solution of the options considered. This is due to the environmental credit achieved by avoided production of virgin bottle grade PET. The main benefit is associated with avoided emissions of particulates and aerosols.

For high population density, where incineration is the MSW treatment option the main conclusions are:

- Incineration is the preferred option from an internal cost perspective
- When total social costs are considered a **separate kerbside collection** achieving a recycling rate of 59-69% is the optimal solution of the options considered. This is due to the environmental credit achieved by avoided production of virgin bottle grade PET. The main benefit is associated with avoided emissions of particulates and aerosols.

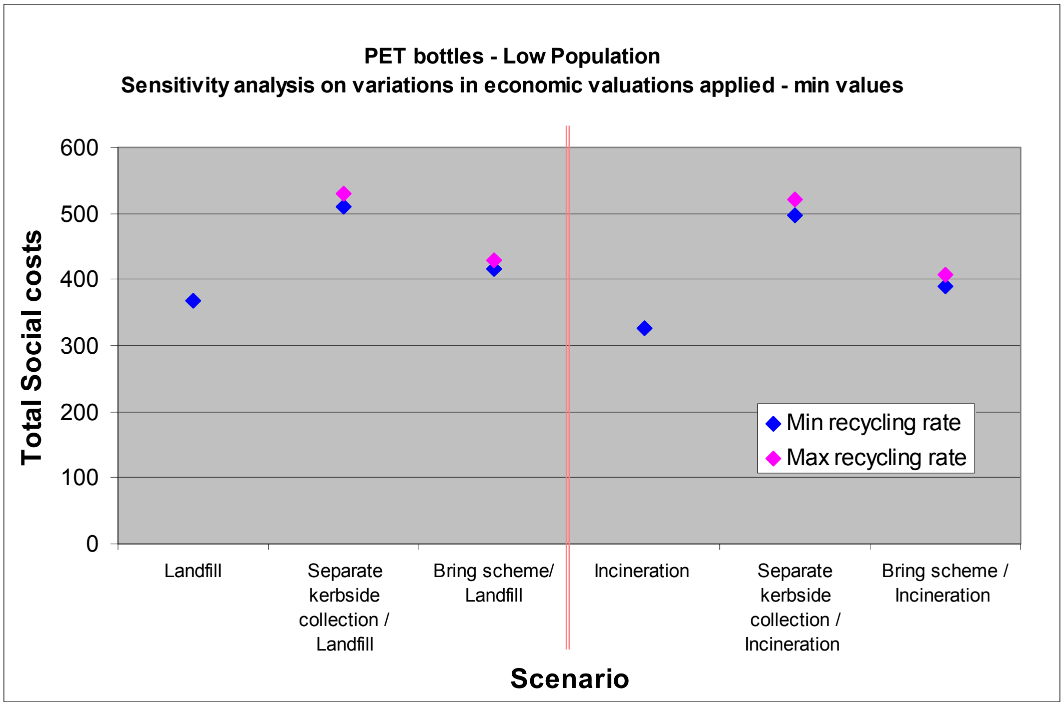
4.2.1.7 Sensitivity analysis: Methodological choices

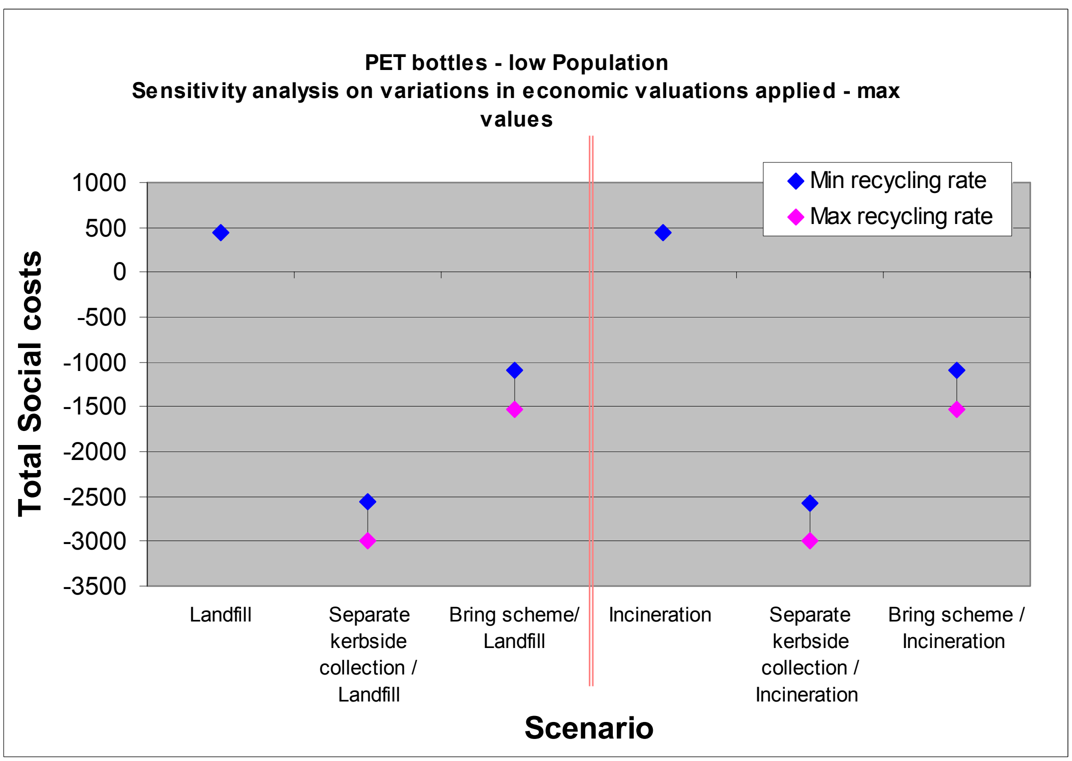
Choice of external valuation values

Graph 3 and Graph 4 show the sensitivity of the analysis to the economic valuations applied to the defined environmental impacts. The graph has been produced by considering the same environmental impact results, but applying different impact assessment valuations (see **Annex 4: Economic valuations applied – sources and derivation** for a list of maximum and minimum valuations applied).

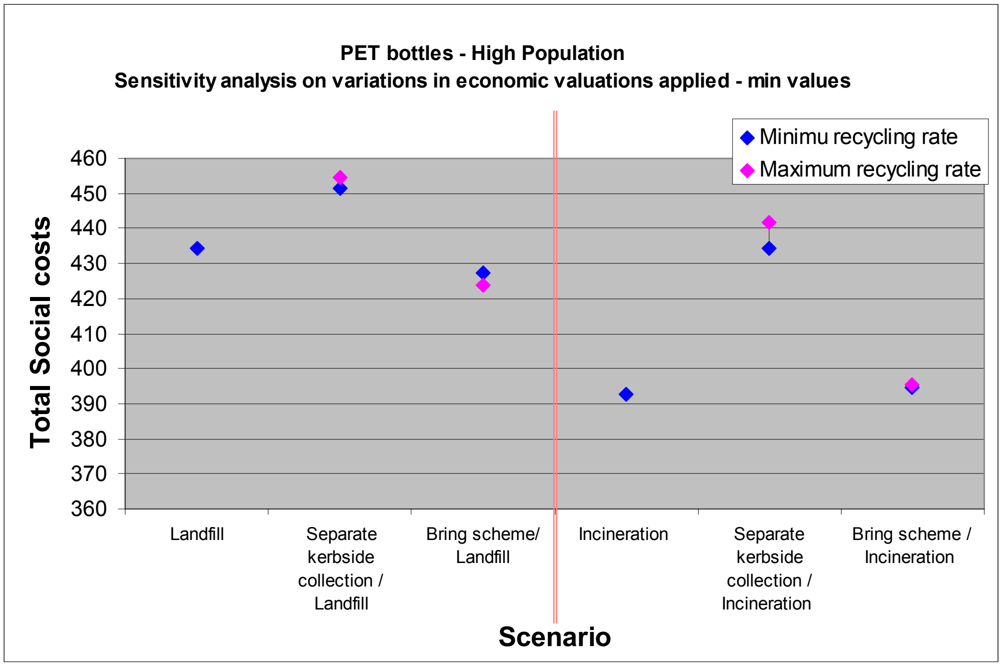
For low and high population density, the results of the analysis and conclusions that can be drawn are extremely dependent on the economic valuations applied.

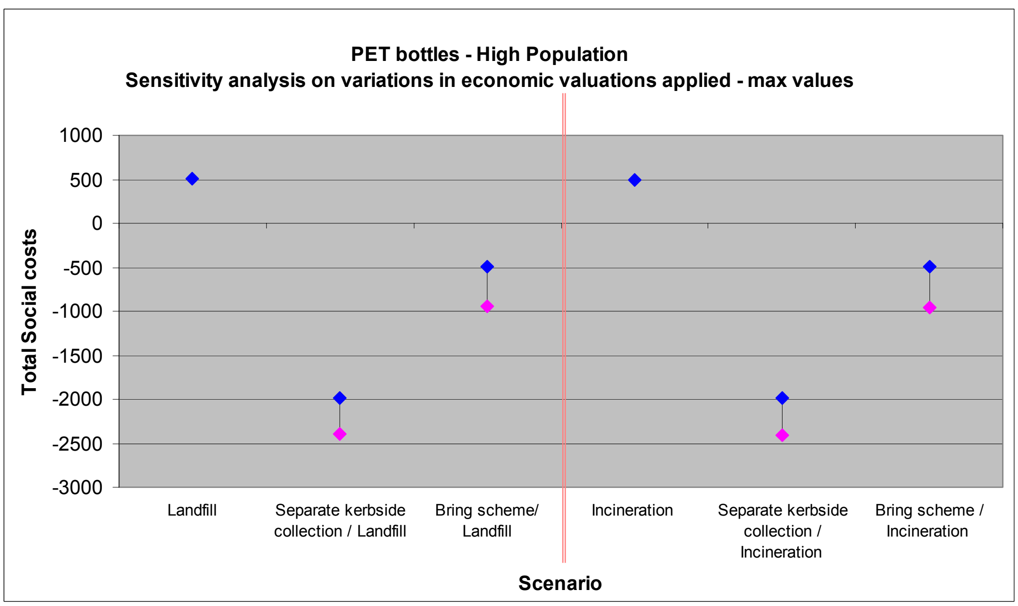
Graph 3 : Sensitivity of the results to the external economic valuations applied - Low population density





Graph 4 : Sensitivity of the results to the external economic valuations applied - High population density

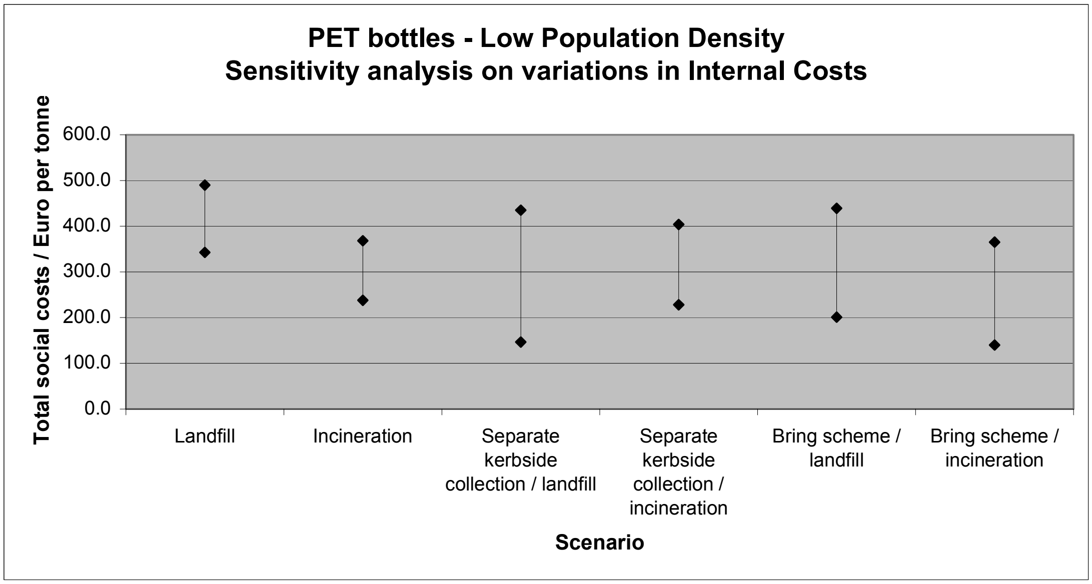




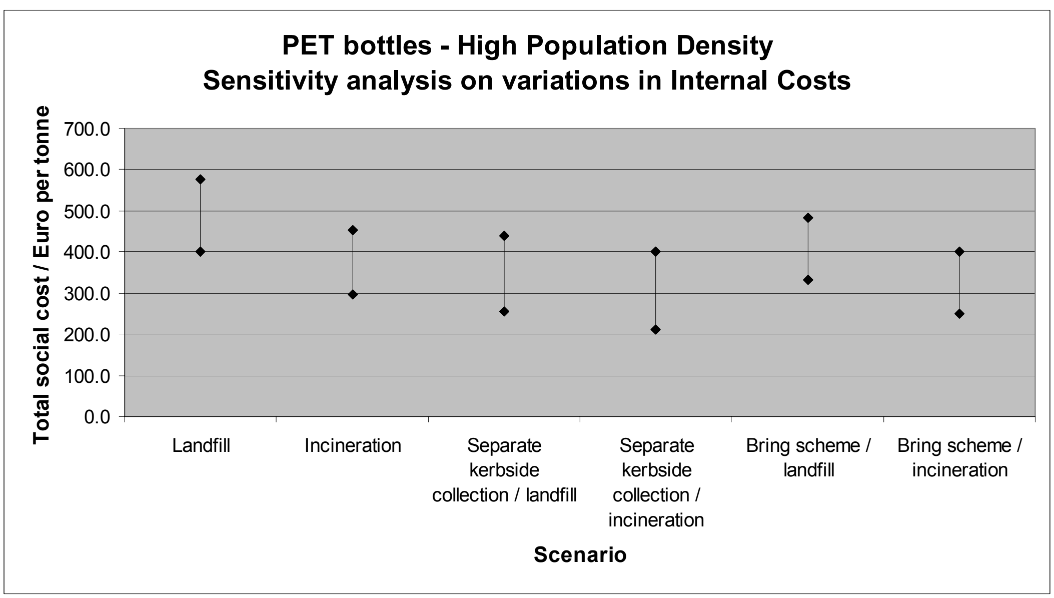
Internal costs

The internal costs applied in this study have been sourced mostly from the UK, France and Belgium. Even where equivalent waste management practices are compared internal costs can vary considerably between Member States, depending on a range of factors such as cost of living and geographical considerations (mountainous regions, islands, etc). In this part of the sensitivity analysis, the effect on the results of considering a +/-20% variation in internal costs is investigated. The results are presented in Graph 5 and Graph 6.

Graph 5 : Sensitivity of the results to the internal economic costs considered - Low population density



Graph 6 : Sensitivity of the results to the internal economic costs considered - High population density

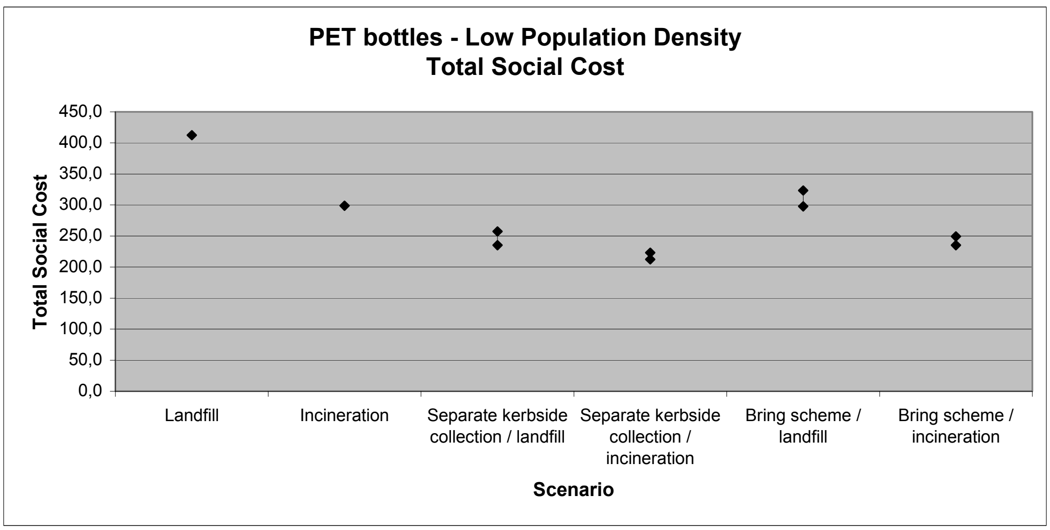


The graphs show that the conclusions that can be drawn from the analysis are highly dependent upon the internal cost assumptions made.

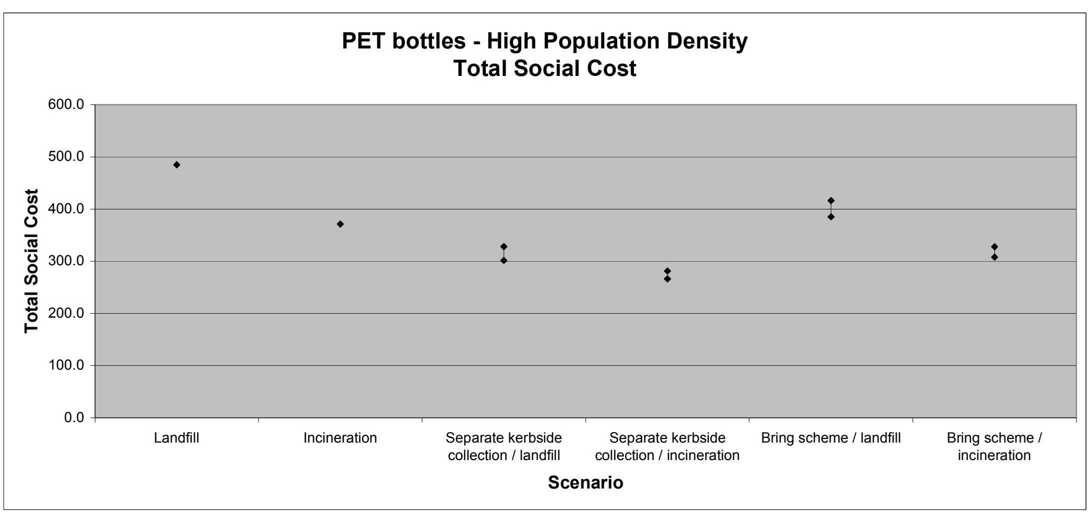
Inclusion of employment as an impact category

In Graph 7 and Graph 8, employment has been added as an external impact category. The graphs show that for low population density where incineration is the alternative MSW option the scenario incorporating separate kerbside collection now becomes the optimal system for the scenario considered.

Graph 7 : Addition of employment as an impact category - low pop. density



Graph 8 : Addition of employment as an impact category - high pop. density

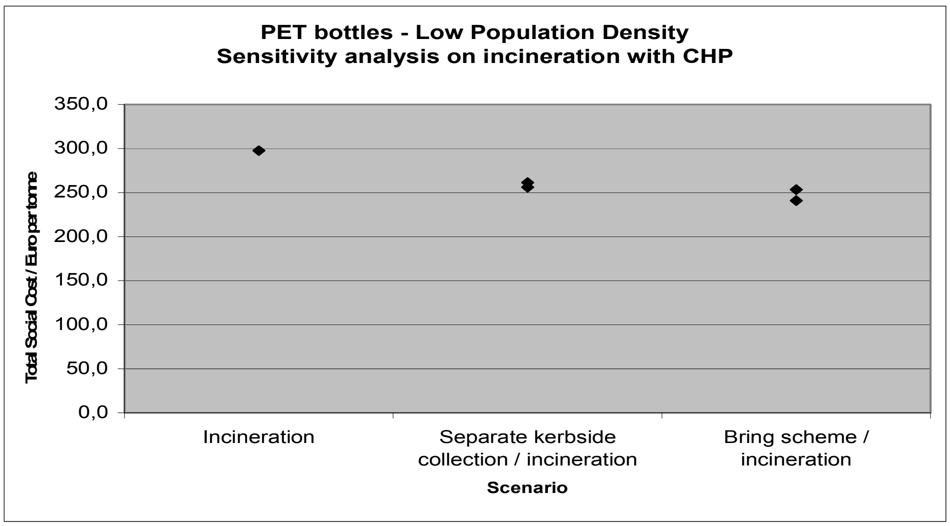


4.2.1.8 Sensitivity analysis: scenario and modelling choices

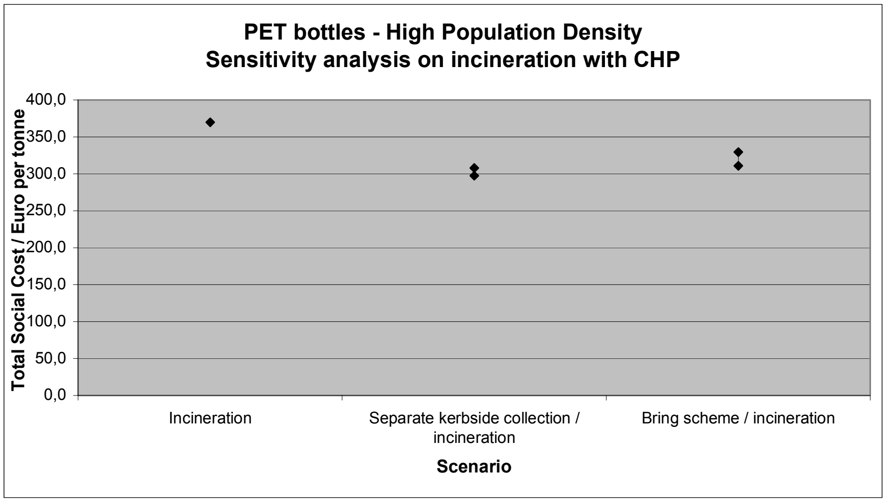
Incineration model

The baseline analysis for scenarios where incineration is the MSW option considers that a proportion of the energy is recovered and converted to electricity. In this part of the sensitivity analysis, the effect of considering combined heat and power is investigated. The effect on the results for high and low population density is presented in Graph 9 and Graph 10.

Graph 9 : Sensitivity of the results to energy recovery assumptions low population density



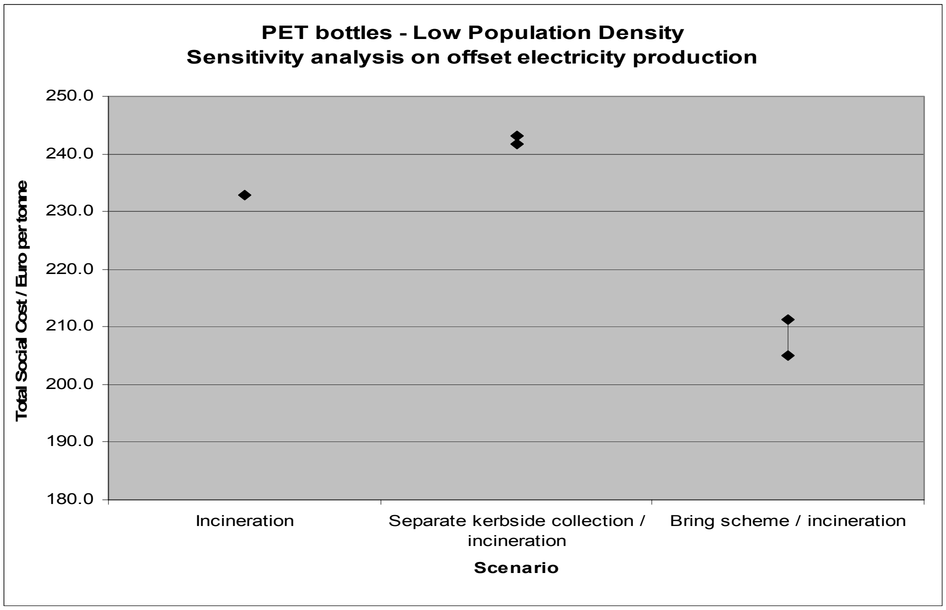
Graph 10 : Sensitivity of the results to energy recovery assumptions - high population density



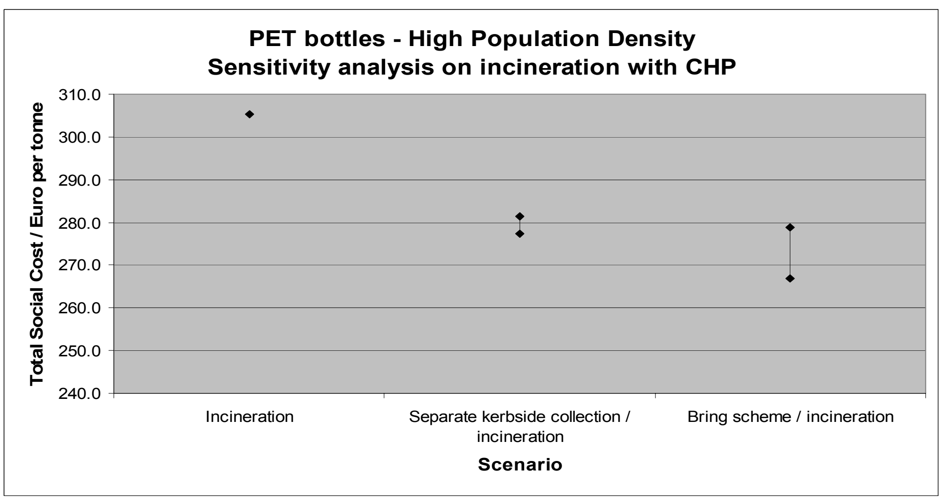
Although considering an efficient CHP scenario reduces the Total Social Cost of incineration, the relative standing of the options is not affected. The results are not sensitive to this assumption.

The baseline incineration model considers that the offset electricity from the incineration process is undelivered average European electricity. Graph 11 and Graph 12 investigate the effect of considering a specific offset electricity production method : coal.

Graph 11 : Sensitivity of results to offset electricity assumption - Low pop. density



Graph 12 : Sensitivity of results to offset electricity assumption - High pop. density



The analysis shows that the total social cost for incineration options is significantly reduced. For low population density, the 100% incineration scenario is now preferable to the scenario incorporating kerbside collection, but the overall conclusion that the bring scheme achieving a recycling rate of 35-45% is the optimal scenario remains valid. For high population density, the bring scheme achieving a recycling rate of 35-45% is now slightly preferable than the kerbside collection. However 100% incineration scenario remains the worst solution.

Transport distances

For the baseline models, the median distance was selected from a range for each transport step. In the baseline analysis, transportation steps are relatively uninfluential in determining the relative standing of the systems. However, in this part of the sensitivity analysis the influence of the assumed transport distances is investigated by compiling best case transport scenarios for landfilling and incineration, and worst cast transport scenarios for kerbside collection and bring schemes. The data applied are summarised in Table 19:

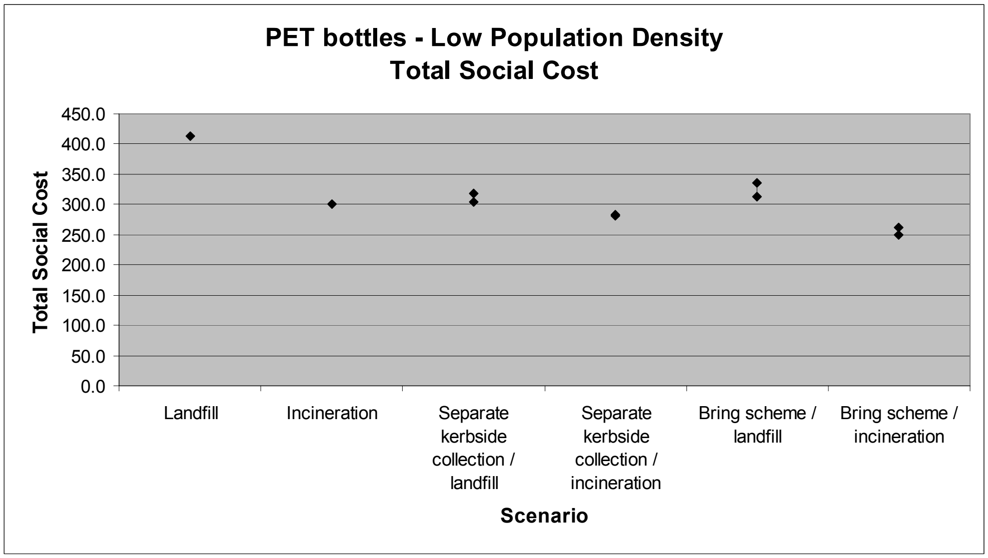
Table 19 : Transport distances

Transportation journey	Baseline distance (km per tonne)	Sensitivity (km per tonne)
Landfill and incineration		
MSW collection, low population density	22.1	12
MSW collection, high population density	9.7	4
Separate kerbside collection		
Kerbside collection round, low pop density	151.1	228
Kerbside collection round, high pop density	64.4	108
Transport from sorting plant to reprocessor	23.05	27
Bring scheme		
Collection from bring bank, low pop density	83.05	124
Collection from bring bank, high pop density	27.6	37
Transport from sorting plant to reprocessor	23.05	27

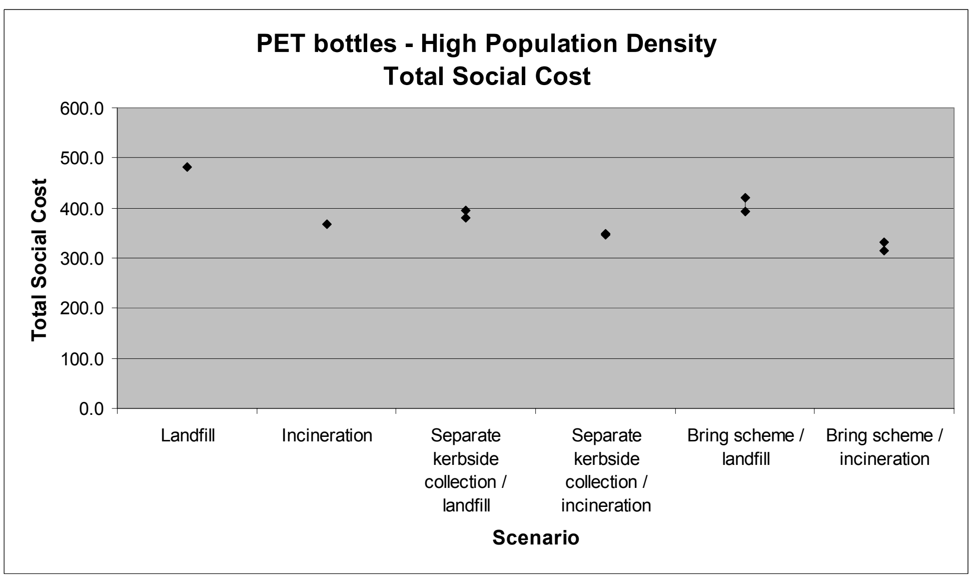
The reason we made this type of analysis is that the objective is to try to find out if the conclusions are robust. The results suggest that the scenarios incorporating recycling are preferable. But what happens if the MSW options are better and the recycling options worse? To find out, we reduce MSW collection round and increase separate kerbside round, etc. This gives us best case MSW and worst case recycling for the sensitivity analysis. If we considered the other end of the scale, (i.e. increase MSW round, reduce recycling transport) all we would do is increase the difference between the options.

The results are presented in Graph 13 and Graph 14.

Graph 13 : Sensitivity of results to transport distances - Low population density

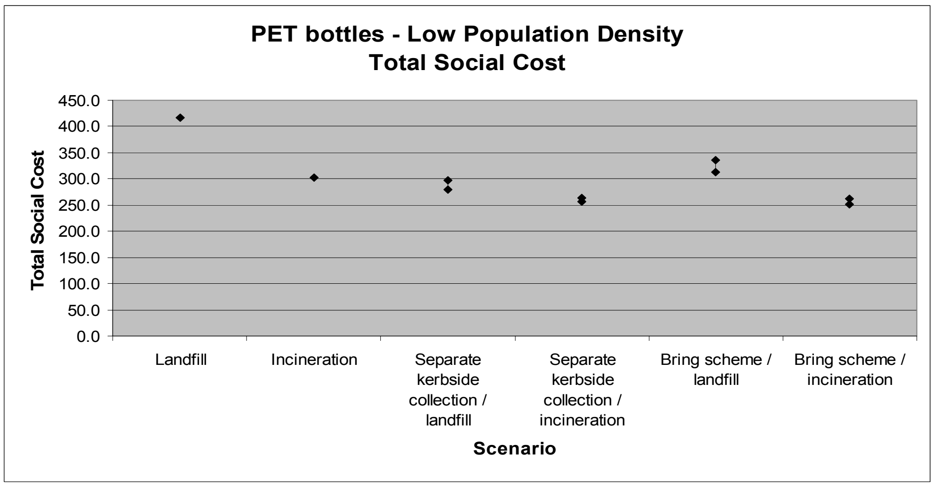


Graph 14 : Sensitivity of results to transport distances - High population density

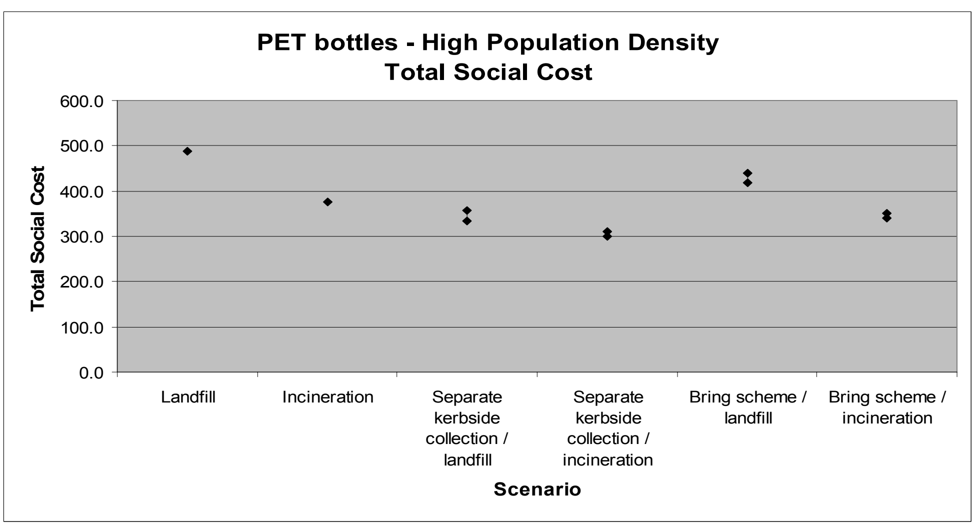


These graphs demonstrate that the results and conclusions drawn are not sensitive to the transport assumptions made for MSW collection, kerbside collection round, collection from bring banks and transport from sorting to reprocessing. It is sensitive for high population density in case of incineration considered as MSW alternative treatment. Bring scheme is then "better" than kerbside collection system, from a total social cost point of view. However, this does not provide any indication of the sensitivity of the results to assumptions made for transport by the public to deliver bottles to the bring bank. This is not easily tested, as no range of data for this transport step was available, just a single value. In order to gauge whether this may be an important parameter the assumed transport distance has been doubled– the results of this sensitivity analysis are presented below.

Graph 15 : Sensitivity of results to consumer transport step - High pop. density



Graph 16 : Sensitivity of results to consumer transport step - High pop. density

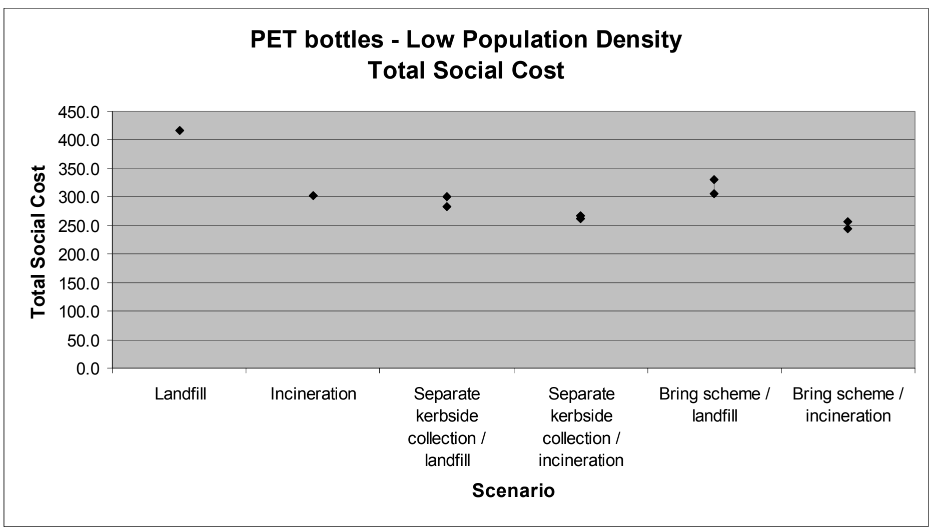


From these graphs it can be seen that doubling distance reduces the favourability of the bring scheme scenario in comparison with the separate kerbside system. The relative standing of the bring scheme scenarios is not altered in comparison to 100% landfill or 100% incineration.

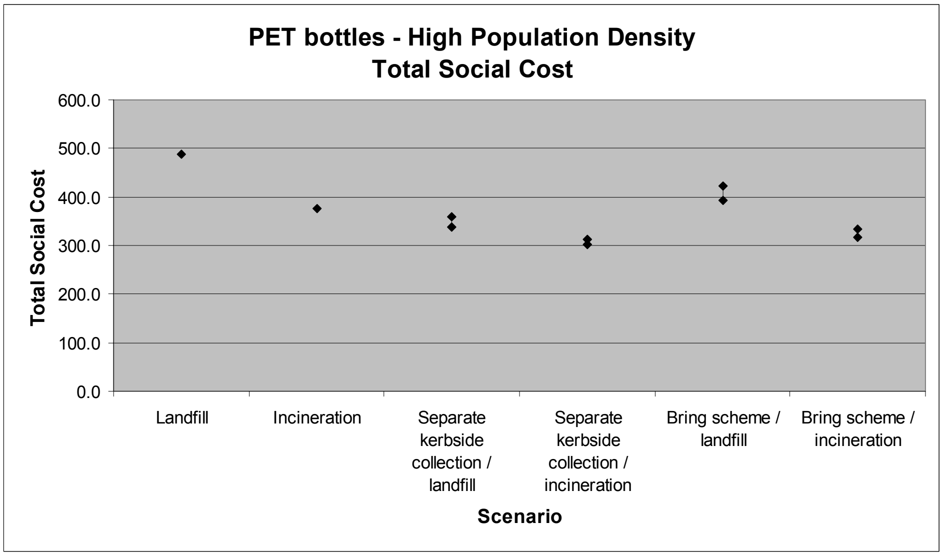
Reprocessing overseas

The baseline scenario assumes that recycling will occur within the EU (within the country of origin of the packaging waste, or in a neighbouring Member State). However, it is common for secondary materials to be reprocessed overseas. The influence of this assumption is investigated in Graph 17 and Graph 18, which add an additional ship transport step to the journey from the sorting plant to reprocessing. Although the total social cost of scenarios incorporating recycling is increased, the relative standing of the scenarios is unaffected.

Graph 17 : Sensitivity of results to overseas transport step - Low population density



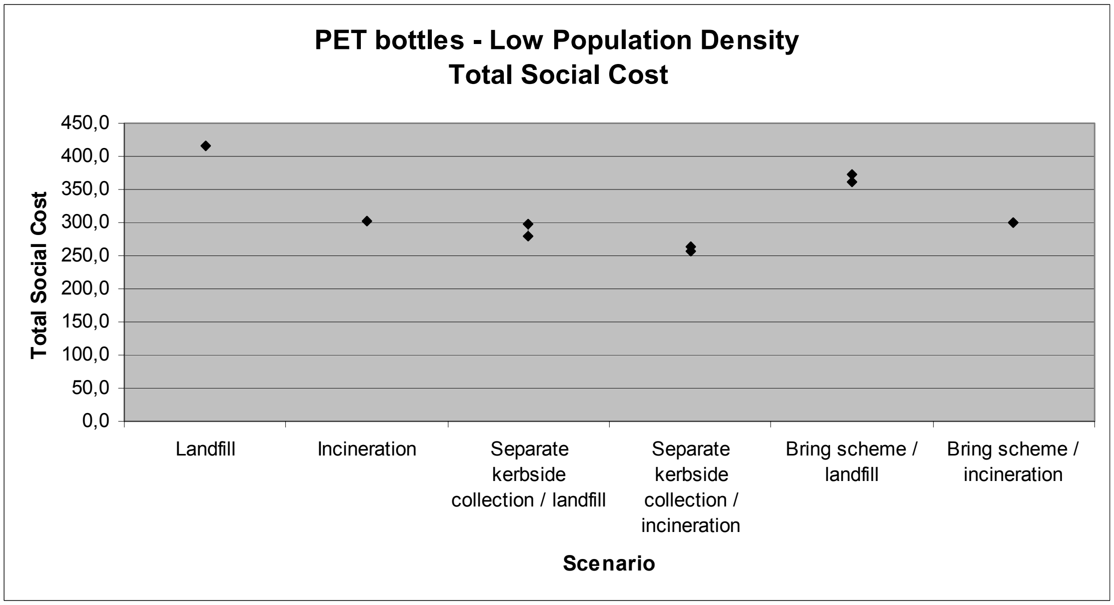
Graph 18 : Sensitivity of results to overseas transport step - High population density



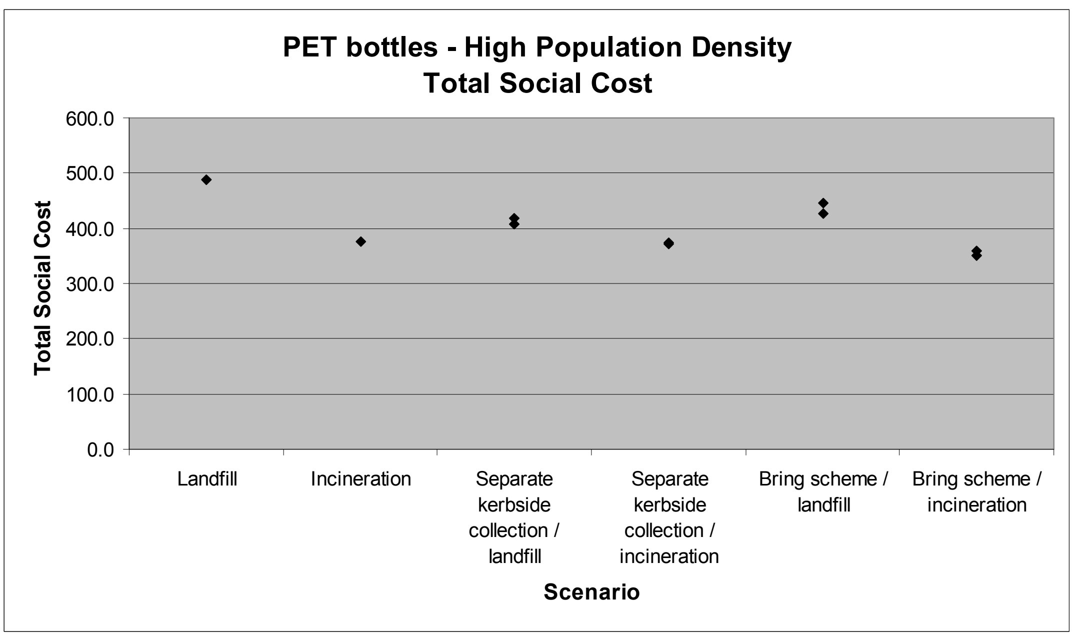
Offset virgin production

The baseline scenarios for PET recycling assume that the recyclate offsets virgin bottle grade PET production, with a save ratio of 1:1. The offset virgin production accounts for the credit which dominates the externalities for the recycling systems. The effect of this assumption on the validity of the results and conclusions is investigated in Graph 19 and Graph 20, where it is assumed that the save ratio is reduced to 0.8:1, and a lower grade of virgin PET is offset.

Graph 19 : Sensitivity of results to virgin production credit - Low pop. density



Graph 20 : Sensitivity of results to virgin production credit - High pop. density



Where landfill is the alternative MSW option, there is no change in the relative standing of the scenarios. However, where incineration is the alternative MSW option, changing the assumptions for the offset virgin production credit could influence the results and conclusions –

in this analysis (high population density) it becomes very difficult to distinguish between 100% incineration and the scenarios that incorporate recycling.

Alternative reprocessing options

The baseline scenarios consider that the PET bottle waste is reprocessed into PET granulate for use in further PET bottle manufacture. Other options are available for reprocessing of PET. In order to investigate the sensitivity of the results to this parameter, Eco-Emballages provided life cycle data for the three layers and ***Supercycle reprocessing*** processes.

In order to protect the confidentiality of the data, specific results are not presented in this report, but the analysis revealed that the environmental externalities for the alternative reprocessing options are of a similar scale due to the similar energy requirements of the processes. In some specific cases where incineration is the MSW option the choice of reprocessing option could make it difficult to distinguish between a 100% incineration scenario and a scenario incorporating recycling.

Using data provided by Eco-Emballages, a sensitivity analysis using LCI data for the ***TBI process*** was also applied. Due to time and resource constraints, the sensitivity analysis considered only the implications of the alternative reprocessing route for Global warming potential and for internal costs. The analysis suggested that although TBI reprocessing may have higher internal costs the process could potentially compete with material recycling from a total social cost perspective.

4.2.1.9 Summary of sensitivity analysis

Parameter investigated	Influence on CBA results	Influence on conclusions drawn
Methodological issues		
Economic values applied	Significant	Critical – applying a maximum and minimum range of economic valuations makes it impossible to distinguish between scenarios
Internal costs	Significant	Critical – applying a +/-20% range of internal costs makes it impossible to distinguish between scenarios

Inclusion of employment as an externality	Significant for kerbside collection scenarios	Critical – valuing employment as an external impact category would change the relative position of some scenarios. Where incineration with energy recovery is the alternative MSW option, the scenarios incorporating separate kerbside collection would now be considered the optimal system, thereby increasing optimal recycling rates for this situation.
Scenario choices		
Incineration model - CHP	Total social cost of incineration scenarios reduced	No effect on relative standing of the scenarios
Incineration model – offset electricity	Total social cost of incineration scenarios reduced. For low population density, 100% incineration is now more favourable than a system incorporating kerbside collection, but a system incorporating a bring scheme remains the optimal of the scenarios considered	Significant for high population density, where incineration is the alternative MSW option, the bring scheme system would now be considered the optimal system, thereby decreasing optimal recycling rates for this situation.
Transport distances – MSW collection round distance, separate kerbside round, collection from bring banks, transport from bring bank to reprocessor	Effect on the relative standing of scenarios	No effect on the choice of optimum scenarios Significant for high population density, where incineration is the alternative MSW option, the bring scheme system would now be considered the optimal system, thereby decreasing optimal recycling rates for this situation.
Transport distances – consumer transport to bring bank	Increases total social cost of bring schemes	Where incineration is the alternative MSW option, choice of optimum scenario could change from system incorporating bring scheme to system incorporating separate kerbside collection. This would increase the optimum recycling rate
Overseas reprocessing	Total social cost of scenarios incorporating recycling is increased, but no change in relative standing of the scenarios	No effect on the choice of optimum scenarios
Offset virgin production	Total social costs of scenarios incorporating recycling is increased. Where landfill is the MSW option, there is no change in the relative standing of the scenarios. In high population density, where incineration is the MSW option, it becomes impossible to choose between the scenarios	Where landfill is MSW option, no effect on choice of optimum scenario Where incineration is MSW option, no obvious optimum scenario and therefore no obvious optimum recycling rate, in case of high population density.
Alternative reprocessing options	General scale of externalities remains the same.	Could affect the choice of optimum scenario under certain circumstances

4.2.2 Steel packaging from household sources

18 scenarios were modelled taking into account the following parameters :

- low and high population density
- landfill, incineration with energy recovery but without slags recovery and incineration with energy and slags recovery as alternative MSW treatment options
- no selective collection, kerbside collection and bring scheme as potential collection systems.

Results are compared from total social cost perspective, and the optimum system for the scenarios considered is determined according to the methodology described in chapter 3.4.1. (see Table 20)

Table 20 : Optimum systems for steel packaging

	Low population density	High population density
Landfill	Bring scheme (Although the difference between all scenarios is very small)	No selective collection and bring scheme (because the difference between the systems is negligible)
Incineration without slags recovery	Bring scheme	No selective collection and bring scheme (because the difference between the systems is negligible)
Incineration with slags recovery	No selective collection	No selective collection

Detailed results of the CBA and the sensitivity analysis are presented in **Annex 10 : Presentation of CBA results for recycling case studies**.

4.2.3 Aluminium packaging from household sources

4.2.3.1 Cans

18 scenarios were modelled taking into account the following parameters :

- low and high population density
- landfill, incineration with energy recovery but without slags recovery and incineration with energy and slags recovery as alternative MSW treatment options

- no selective collection, kerbside collection and bring scheme as potential collection systems.

Results are compared from total social cost perspective, and the optimum system for the scenarios considered is determined. Results are given in Table 21.

Table 21 : Optimum systems for aluminium cans

	Low population density	High population density
Landfill	Separate kerbside collection scheme	Separate kerbside collection scheme
Incineration without slags recovery	Separate kerbside collection scheme	Separate kerbside collection scheme
Incineration with slags recovery	No selective collection	Bring scheme

Detailed results of the CBA and the sensitivity analysis are given in **Annex 10 : Presentation of CBA results for recycling case studies**.

4.2.3.2 Other rigid and semi-rigid application

18 scenarios were modelled taking into account the following parameters :

- low and high population density
- landfill, incineration with energy recovery but without slags recovery and incineration with energy and slags recovery as alternative MSW treatment options
- no selective collection, kerbside collection and bring scheme as potential collection systems.

Results are compared from total social cost perspective, and the optimum system for the scenarios considered is determined. Results are given in Table 22.

Table 22 : Optimum systems for other rigid and semi-rigid aluminium packaging

	Low population density	High population density
Landfill	separate kerbside collection	separate kerbside collection and bring scheme
Incineration without slags recovery	separate kerbside collection and bring scheme	
Incineration with slags recovery	separate kerbside collection and bring scheme	

Detailed results of the CBA and the sensitivity analysis are given in **Annex 10 : Presentation of CBA results for recycling case studies**.

4.2.4 Paper and board packaging from household sources

12 scenarios were modelled taking into account the following parameters :

- low and high population density
- landfill and incineration with energy recovery as alternative MSW treatment options
- no selective collection, kerbside collection and bring scheme as potential collection systems.

Results are compared from total social cost perspective, and the optimum system for the scenarios considered is determined. Results are given in Table 23.

Table 23 : Optimum systems for paper & board packaging

	Low population density	High population density
Landfill	kerbside collection scheme	kerbside collection scheme
Incineration with slags recovery	kerbside collection scheme	kerbside collection scheme

Detailed results of the CBA and the sensitivity analysis are given in **Annex 10 : Presentation of CBA results for recycling case studies**.

4.2.5 LBC from household sources

16 scenarios were modelled taking into account the following parameters :

- low and high population density
- landfill and incineration with energy recovery as alternative MSW treatment options
- landfill and incineration with energy recovery as recycling rejects treatment options
- for scenarios incorporating material recycling of fibres, landfill and incineration with energy recovery as alternative treatment options for the rejected plastic film/aluminium foil from recycling
- no selective collection, kerbside collection and bring scheme as potential collection systems.

Other recycling routes such as recovery in a cement kiln were not considered due to the necessary limitation of the number of scenarios and to a lack of readily available LCI data to support the analysis."

Results are compared from total social cost perspective, and the optimum system for the scenarios considered is determined. Results are given in Table 24.

Table 24 : Optimum systems for LBC packaging

MSW treatment	Rejects treatment	Low pop. density	High pop. density
Landfill	Landfill	No selective collection	No selective collection
Landfill	Incineration	No selective collection	No selective collection
Incineration with slag recovery	Incineration	No selective collection	No selective collection

Detailed results of the CBA and the sensitivity analysis are given in **Annex 10 : Presentation of CBA results for recycling case studies**.

4.2.6 Mix plastic packaging from household sources

12 scenarios were modelled taking into account the following parameters :

- low and high population density
- landfill and incineration with energy recovery as alternative MSW treatment options
- no selective collection, kerbside collection with mechanical recycling or with treatment in blast furnace as potential collection & recycling options.

Results are compared from total social cost perspective, and the optimum system for the scenarios considered is determined. Results are given in Table 25.

Table 25 : Optimum systems for mix plastic packaging

MSW treatment	Low pop. density	High pop. density
Landfill	No selective collection	No selective collection
Incineration with slag recovery	No selective collection	No selective collection

Detailed results of the CBA and the sensitivity analysis are given in **Annex 10 : Presentation of CBA results for recycling case studies**.

4.2.7 Industrial case studies

For the 2 industrial case studies, i.e. LDPE plastic films and cardboard, we calculated the minimum packaging waste production under which the selective collection is not beneficial.

The external benefits (EB) of collecting and recycling industrial packaging waste has been calculated as 11.7 EURO/t (corrugated board) and 208 EURO/t (PE film).

Collecting and transporting corrugated board and PE films as mixed waste is often cheaper than collecting and transporting source sorted packaging. There is thus an additional collection cost (ACC) to collect selectively.

The annual production of industrial packaging waste for which the ACC = EB is

- 5.5 t/year for cardboard
- 0.01 t/year for LDPE plastic films

Above this waste production the environmental benefits outweigh the additional internal cost for the selective collection.

This means that, from a cost-benefit viewpoint, **the companies who produce more waste than 0.01 t of plastic film or 5.5 t of** corrugated board **per year should have a selective collection scheme** to recycle it. As the "break-even" amount is very low for PE films, it can be concluded that selective collection of industrial packaging should be systematic throughout the EU. As there are limits to the modelling, it has been assumed for this study that 95% of the industrial sites (percentage in packaging weight) should make the selective collection of packaging.

This means that the recycling rates that should achieved for the industrial packaging is equal to "*95% of the collection rate achievable when a selective collection scheme is set up*" multiplied by the fraction of the waste that may be recycled for safety (in contact with hazardous products) or technical reasons (too high material degradation). In other words, the recycling rates that minimise (read "optimise") the social cost of the industrial packaging waste management are the ones given in Table 7 on page 42 multiplied by 95%.

4.3 Suggested recycling targets

4.3.1 Determination of optimum systems and recycling ranges

For each combination of parameters (i.e. population density, alternative MSW treatment options), the "optimal" collection system is considered to be the collection system corresponding to the scenario modelled with the lowest total social cost. The scenarios and their results are discussed in chapter 4.2 and summarised in Table 26

Table 26 : Optimum collection systems per case study, based on CBA

	Low population density		High population density	
	Landfill	Incineration	Landfill	Incineration
PET bottles	Kerbside	Bring	Kerbside	Kerbside
Steel packaging	Bring	No SC	No or bring	No SC
Al cans	Kerbside	No SC	Kerbside	Bring
Rigid & semi-rigid Al packaging excluding cans	Kerbside	Kerbside or bring	Kerbside or bring	Kerbside or bring
Paper and board packaging	Kerbside	Kerbside	Kerbside	Kerbside
LBC	No SC	No SC	No SC	No SC
Mix plastic packaging	No SC	No SC	No SC	No SC

However the choice of optimum collection system has also to consider communication aspects. It mainly means to take into account the understanding and behaviour of the consumer. E.g. the consumer will not be able to make the difference between aluminium and steel cans. Therefore it assumed that both packaging material should be collected with the same collection systems.

Insofar as the optimal collection systems, based on CBA calculation, are not the same for all metals packaging, weighted Total Social Costs are compared in order to determine the common optimal system. The weighting parameters are the amount of packaging put on the market. The common optimal collection systems are given in Table 27.

Table 27 : Optimal collection systems for metal packaging

	Low population density		High population density	
	Landfill	Incineration	Landfill	Incineration
Steel packaging	Bring and kerbside	No SC	Kerbside	No SC
Al cans	Bring and kerbside	No SC	Kerbside	No SC
Rigid & semi-rigid Al packaging excluding cans	Bring and kerbside	No SC	Kerbside	No SC

On the other hand the models do not consider scale effects. Therefore PET bottles, LBC and metals packaging could be collected with different collection systems provided that the collected amount is sufficient to justify a frequency of at least once a month.

The "optimal" recycling rate is considered to be the recycling rate achievable by the "optimal" collection system. Therefore Table 28 gives the range of "optimal" recycling rates for each case study.

Table 28 : Optimal recycling ranges per case study

	Low population density		High population density	
	Landfill	Incineration	Landfill	Incineration
PET bottles	70-80%	35-45%	59-69%	59-69%
Steel packaging	15-60%	80%	40-60%	80%
Al cans	31-55%	76%	45-55%	76%
Rigid & semi-rigid Al packaging excluding cans	3-17%	50%	3-8%	50%
Paper and board packaging	61-71%	61-71%	55-65%	55-65%
LBC	0%	0%	0%	0%
Mix plastic packaging	0%	0%	0%	0%

4.3.2 Determination of optimal recycling rate for each Member State

This chapter concerns the determination of ranges of global optimal recycling rate for each Member States. The global recycling rate takes into account all the packaging whatever their origin (i.e. household and industrial sources).

For each application, optimal recycling rates were determined for each of the 4 categories (population density / MSW treatment) (see Table 28). The optimum target for an application in a specific Member State is the weighted average of the 4 targets related to the 4 categories. The weighting factors are the ones given in Table 11.

In order to obtain ranges of recycling targets, the minimum and maximum optimal recycling rates are successively applied to the packaging mix of each Member State.

Table 29 illustrates the calculation of the range of global optimal recycling rate for the European Union. The packaging mix considered is the sum of the packaging amount arising in all the Member States.

Table 29 : Calculation of minimum and maximum recycling rate for the EU

Minimum recycling rates

EU	2000		Amount of	Optimised recycling/reuse target		Amount of waste
	Material	Application	waste	Low packaging amount	High packaging amount	to be recycled
Industrial waste			1000 t/year	5%	95%	1000 t/year
	Plastics	Total	4.018			1.348
		LDPE films	1.651	0%	55%	869
		Other	2.367	0%	21%	479
	Wood		7.812	0%	50%	3.711
	Steel		1.818	0%	80%	1.382
	Cardboard		18.823	0%	64%	11.444
	glass		1.789	0%	50%	850
	Other		289	0%	0%	0
Total			34.549			18.735
		Global Target Industrial waste				54%

				Percentage of population living in areas where population density is L/H and waste are I/L				
				Low		High		
				landfill	Inc.	landfill	Inc.	
Household waste				27%	12%	41%	20%	
	Plastics		5.871					1.374
		PET bottles	1.502	70%	35%	59%	59%	887
		LPDE films	1.205	0%	0%	0%	0%	0
		HDPE bottles	1.015	57%	28%	48%	48%	487
		other	2.150	0%	0%	0%	0%	0
	Steel		2.214	15%	80%	40%	80%	1.022
	aluminium	total	391,6					96
	Wood		128	0%	0%	0%	0%	0
	Cardboard	total	5.947	61%	61%	55%	55%	3.411
	composites	liquid beverage c	710	0%	0%	0%	0%	0
		mainly based on	109	0%	0%	0%	0%	0
		mainly based on	165	0%	0%	0%	0%	0
		mainly based on	86	0%	0%	0%	0%	0
	Glass		13.445	73%	73%	42%	42%	7.288
	Other		65	0%	0%	0%	0%	0
Total			29.132					13.191
	Global Target Household waste							45%

Total			63.681					31.926
				Global target (Industrial + Household waste)				50%

			Maximum recycling rates					
EU	2000		Amount of	Optimised recycling/reuse target				Amount of waste
	Material	Application	waste	Low packaging amount		High packaging amount		to be recycled
Industrial waste			1000 t/year	5%		95%		1000 t/year
	Plastics	Total	4 018					2 111
		LDPE films	1 651	0%		75%		1 182
		Other	2 367	0%		41%		929
	Wood		7 812	0%		70%		5 195
	Steel		1 818	0%		90%		1 555
	Cardboard		18 823	0%		80%		14 306
	glass		1 789	0%		83%		1 411
	Other		289	0%		0%		0
Total			34 549					24 577
				Global Target Industrial waste				71%
				Percentage of population living in				
				areas where population density is L/H and waste are I/L				
				Low		High		
				landfill	Inc.	landfill	Inc.	
Household waste				27%	12%	41%	20%	
	Plastics		5 871					1 626
		PET bottles	1 502	80%	45%	69%	69%	1 037
		LPDE films	1 205	0%	0%	0%	0%	0
		HDPE bottles	1 015	67%	38%	58%	58%	589
		other	2 150	0%	0%	0%	0%	0
	Steel		2 214	60%	80%	60%	80%	1 472
	aluminium	total	391.6					122
	Wood		128	0%	0%	0%	0%	0
	Cardboard	total	5 947	71%	71%	65%	65%	4 006
	composites	liquid beverage	710	0%	0%	0%	0%	0
		mainly based c	109	0%	0%	0%	0%	0
		mainly based c	165	0%	0%	0%	0%	0
		mainly based c	86	0%	0%	0%	0%	0
	Glass		13 445	83%	83%	91%	91%	11 811
	Other		65	0%	0%	0%	0%	0
Total			29 132					19 036
				Global Target Household waste				65%
Total			63 681					43 613
			Global target (Industrial + Household waste)					68%

Detailed tables per Member State are given in **Annex 11 : Calculation of recycling rates per Member States**.

The minimum and maximum recycling targets are summarised per Member States in Table 30. They are detailed per industrial and household packaging sources.

Table 30 : Summary of the ranges of optimal recycling rates per Member States

	Global Target Industrial waste		Global Target Household waste		Global target (Industrial + Household waste)	
	Min	Max	Min	Max	Min	Max
Austria	56%	74%	42%	60%	49%	67%
Belgium	54%	70%	42%	65%	48%	67%
Denmark	54%	70%	53%	66%	53%	68%
Finland	57%	73%	35%	48%	48%	63%
France	53%	72%	45%	68%	50%	70%
Germany	56%	72%	45%	71%	51%	**72%**
Greece	53%	70%	39%	52%	46%	61%
Ireland	50%	67%	27%	38%	**40%**	54%
Italy	54%	71%	44%	65%	49%	68%
Luxembourg	54%	70%	46%	66%	50%	68%
The Netherlands	55%	71%	44%	64%	51%	68%
Portugal	57%	75%	46%	64%	47%	65%
Spain	50%	66%	47%	65%	49%	65%
Sweden	59%	76%	44%	54%	52%	66%
United Kingdom	56%	72%	39%	64%	49%	69%
EU	54%	71%	45%	65%	50%	68%

Depending on MS and assumptions, the optimum recycling rate varies from 40% to 72%.

There is no uniform optimum recycling rate valid throughout EU. The optimum can vary from MS to MS by as much as 31% (in absolute terms, i.e. from the minimum of the minimum targets to the maximum of the maximum targets).

4.3.3 Determination of optimal recycling rate for each packaging material (at the EU level)

The optimum recycling target for a material (e.g. plastics) in a specific Member State is the weighted average of the optimum targets of the different applications (e.g. for plastics: PET bottles, HDPE containers, LDPE industrial films, LDPE household films and others) in this Member State.

In order to complete the previous data Table 31 summarised the range of recycling rate per material for the European Union.

Table 31 : Recycling rate per material

	Minimum recycling rate	Maximum recycling rate
Plastic	28%	38%
Steel	60%	75%
Aluminium	25%	31%
Wood	47%	65%
Paper & board	60%	74%
Glass	53%	87%
Composites	0%	0%

4.3.4 Sensitivity analysis

4.3.4.1 Sensitivity analysis to the plastics packaging mix

Data (for 1997) published in 1999 by APME show different amounts of post user plastics packaging by origin (i.e. 73% of household packaging instead of 60% in the current study). It should be noted that APME data concern the year 1997 and the weight of household packaging decreased during the last years. This can partially explain the difference between both data sets.

However the sensitivity analysis assesses the effect of using the APME data on the global recycling targets. The change in plastic waste composition has been done in practice as follows : 13% industrial films (optimum recycling rate = 55-75%) become 13% household films (optimum recycling rate = 0%).

The recycling rate per material for 2000 would be 21%-28% instead of 28%-38%.

4.3.4.2 Sensitivity analysis to the packaging mix forecast at the horizon 2006

Global recycling targets were calculated with the packaging mix forecast for 2000. Insofar new targets will be applied in 2006, the influence of the packaging mix and the evolution of the population density and the alternative MSW treatment on the results are analysed.

The main constraint is the data availability. Forecasts for 2006 are not always available and have to be used with caution.

The packaging mix modelled for 2006 is given in **Annex 6: Packaging mix by Member State**. Table 32 gives the global recycling rates that should be achieved considering the packaging mix modelled for 2006.

Table 32 : Recycling targets per Member State based on estimated packaging mix in 2006

	Min			Max		
	Industrial	Household	Total	Industrial	Household	Total
Austria	56%	41%	49%	74%	59%	66%
Belgium	54%	41%	47%	70%	62%	66%
Denmark	54%	49%	52%	70%	62%	67%
Finland	54%	39%	47%	72%	50%	62%
France	53%	46%	50%	72%	69%	70%
Germany	55%	42%	50%	72%	64%	68%
Greece	52%	38%	45%	70%	51%	60%
Ireland	49%	43%	47%	66%	60%	64%
Italy	54%	45%	50%	71%	66%	68%
Luxembourg	54%	47%	51%	70%	67%	68%
Netherlands	54%	42%	49%	71%	60%	66%
Portugal	52%	48%	49%	70%	67%	67%
Spain	51%	48%	49%	66%	66%	66%
Sweden	57%	42%	50%	74%	53%	65%
United Kingdom	55%	38%	48%	72%	61%	67%
EU[11]	54%	45%	50%	71%	64%	68%

Depending on MS and assumptions, the optimum recycling rate varies from 45 to 70%.

There is no uniform optimum recycling rate valid throughout EU. The optimum can vary from MS to MS by as much as 25% (in absolute terms, i.e. from the minimum of the minimum targets to the maximum of the maximum targets).

[11] Packaging mix modelled for the EU is the sum of packaging mix of all the Member states

In general, the evolution of the packaging mix between 2001 and 2006 has only little influence on the global recycling targets (mainly because the relative evolution is rather limited).
However the influence of the packaging mix evolution on the "optimum" recycling rates for household packaging is larger for Austria, Finland, Germany, Ireland and The Netherlands.
Regarding the specific targets for Portugal, the influence of the packaging mix evolution is also substantial but it is counterbalanced by the evolution of the population density and alternative MSW treatment options so that the "optimum" recycling rates show only a slight evolution.

The sensitivity of the material targets to the packaging mix was also examined (Table 33).

Table 33 : Sensitivity of the material recycling rates to the packaging mix

	2000		2006	
	Min	Max	Min	Max
Plastic	28%	38%	26%	36%
Steel	60%	75%	63%	76%
Aluminium	25%	31%	26%	31%
Wood	47%	65%	47%	66%
Paper & board	60%	74%	60%	74%
Glass	53%	87%	53%	87%
Composites	0%	0%	0%	0%

Considering the uncertainty on the assumptions, the evolution of the packaging mix does not strongly influences the material recycling rates.

4.4 Reuse

The complete results concerning reuse are presented in **Annex 12 : Presentation of CBA results for reuse case studies**.

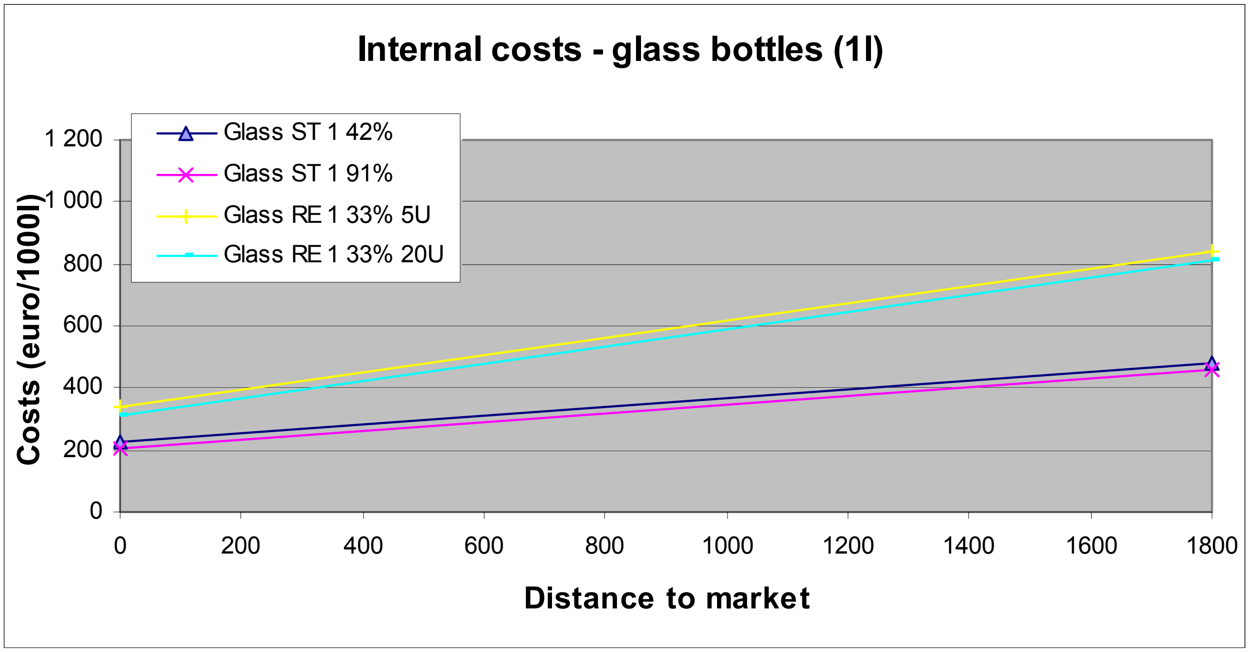
4.4.1 Glass

The results concerning the internal, external and total social costs for glass are summarised in Graph 21, Graph 22 and Graph 23 (next pages).

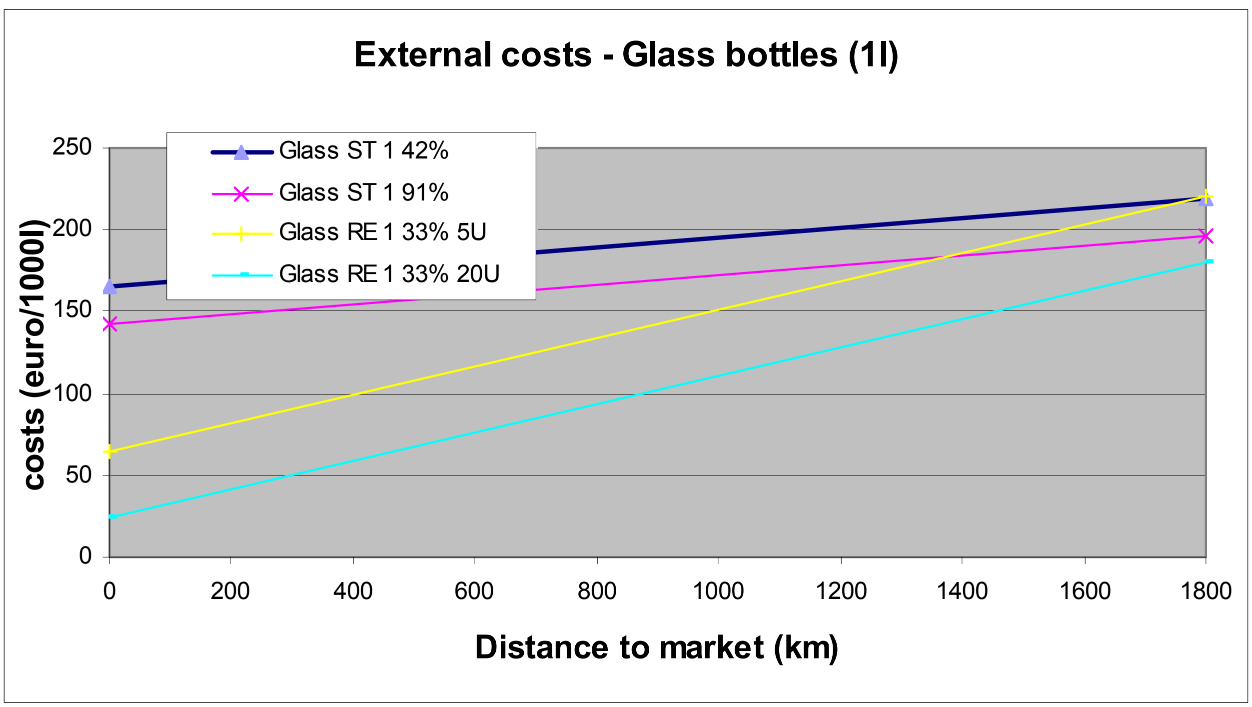
Conclusions are :

- Internal costs dominate the total social cost (between 59 and 93%).
- Single trip bottles are always cheaper (From an internal cost perspective).
- External costs of Single trip bottles are higher except for very long distances (>1380-2490 km)
- Total social costs of Single trip bottles are
  - about the same as refillables up to 300 km and
  - lower for distances > 300 km.
- The single trip bottles with a high recycling rate (91%) are slightly better than the others (except refillable 20U for very short distances, i.e. < 100 km). The refillable system (5 uses) has the highest impact.

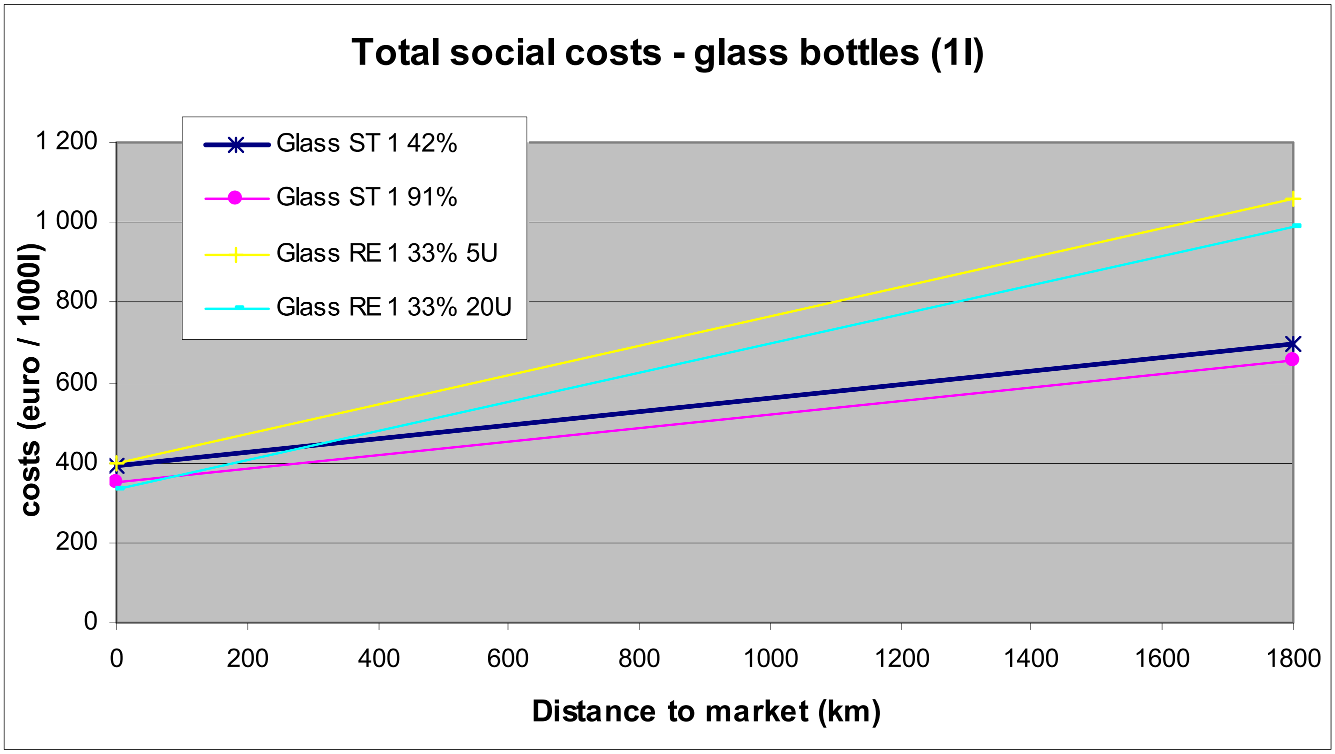
Graph 21 : Internal costs for glass



Graph 22 : External costs for glass



Graph 23 : Total social costs for glass



From these results it can be drawn that :

- The reuse system (20U) is cheaper for relatively short transportation distances[12] (under 100 to 150 km)
- The reuse system (20U) is always better from an environmental point of view

4.4.2 PET

The results concerning the internal, external and total social costs for PET are summarised in Graph 24, Graph 25 and Graph 26 (next pages).

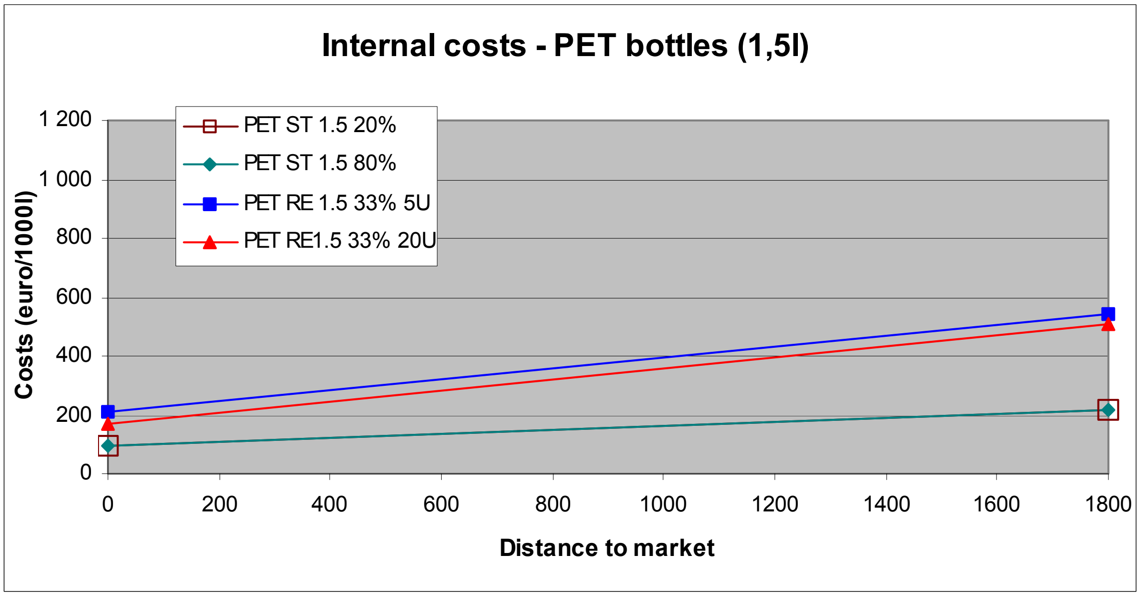
Conclusions are :

- Internal costs dominate the total social cost (between 63 and 94%). Single trip bottles are always cheaper
- External costs of Single trip bottles are higher for short distances and lower for long distances

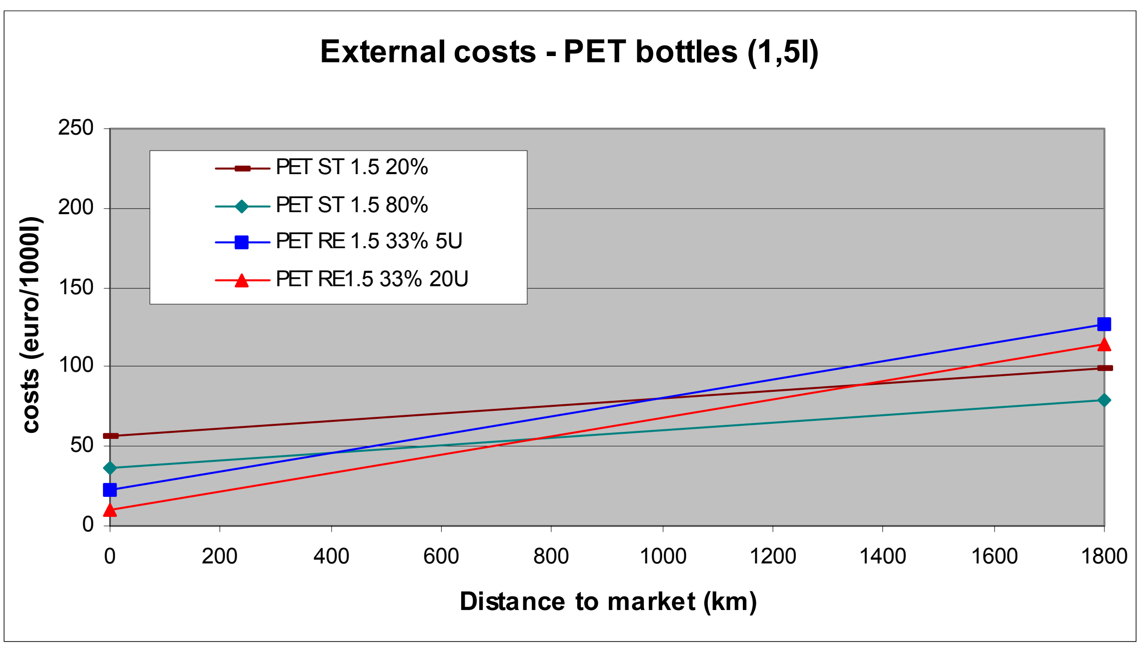
[12] from filler to distribution centre

- Total costs of Single trip bottles are always lower, whatever the distance and the recycling rate.

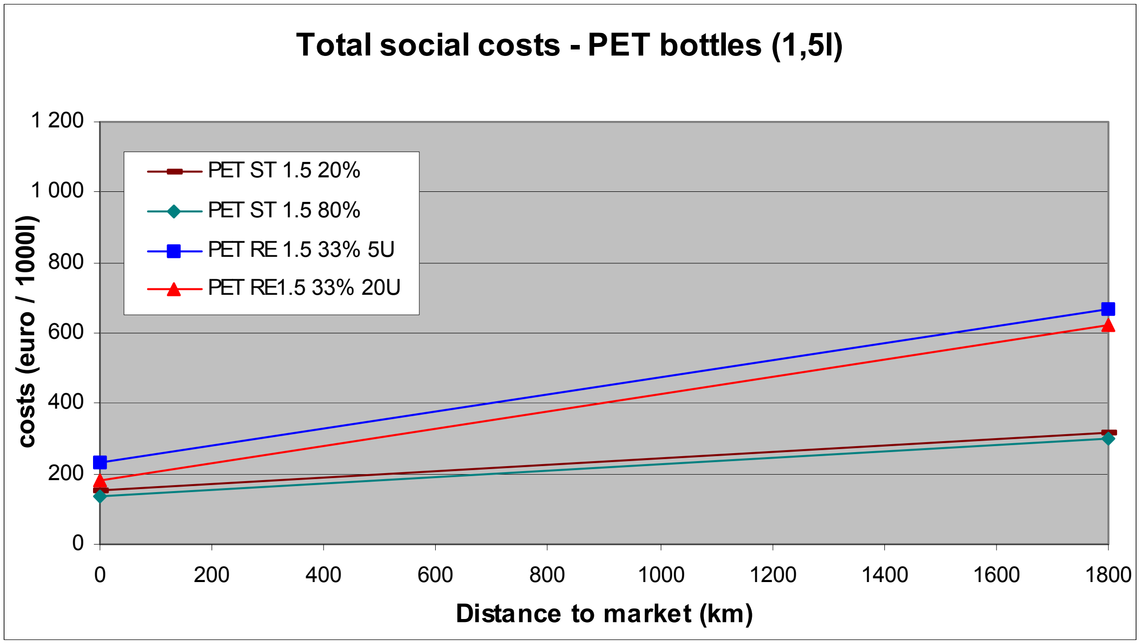
Graph 24 : Internal costs for PET



Graph 25 : External costs for PET



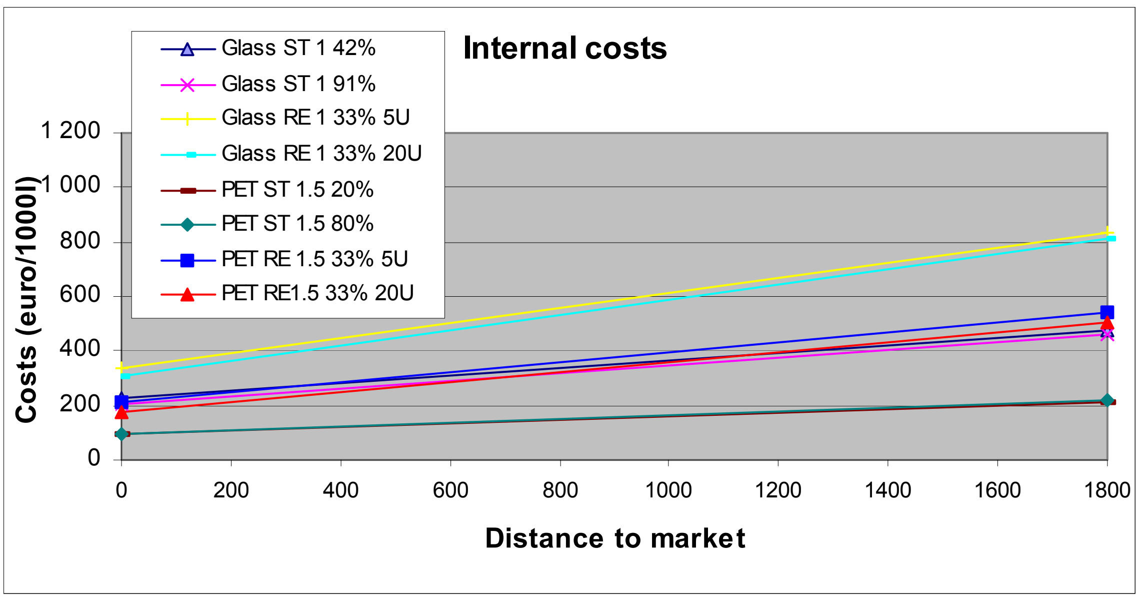
Graph 26 : Total social costs for PET



4.4.3 Glass and PET

The results concerning the internal, external and total social costs for both glass and PET are summarised in Graph 27, Graph 28 and Graph 29 (next pages). The comparison is fair as the same volumes have been used for both packaging materials and the modelled systems are representative of the market (Remark : 1l PET bottles recently appeared on the market but there are still no 1.5 litre glass bottles).

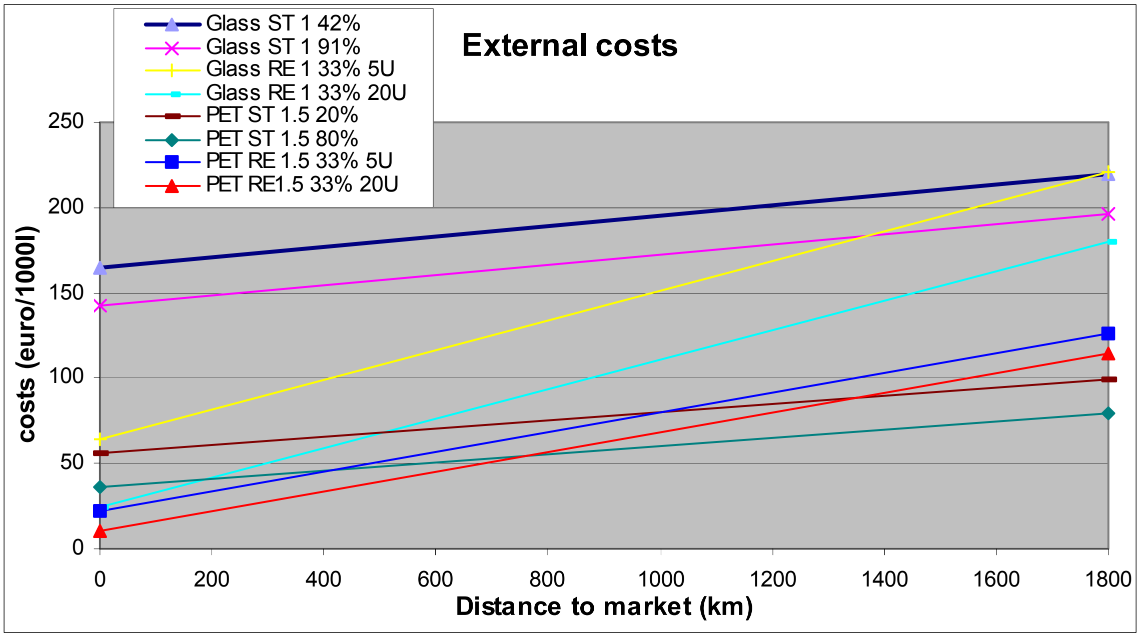
Graph 27 : Internal costs for refillable and non refillable glass (1 l) and PET (1.5l) beverage packaging



From an <u>internal</u> cost perspective,

- PET ST is the best option.
- PET refillable and glass ST are similar but clearly higher than PET ST
- Glass refillable is the most expensive

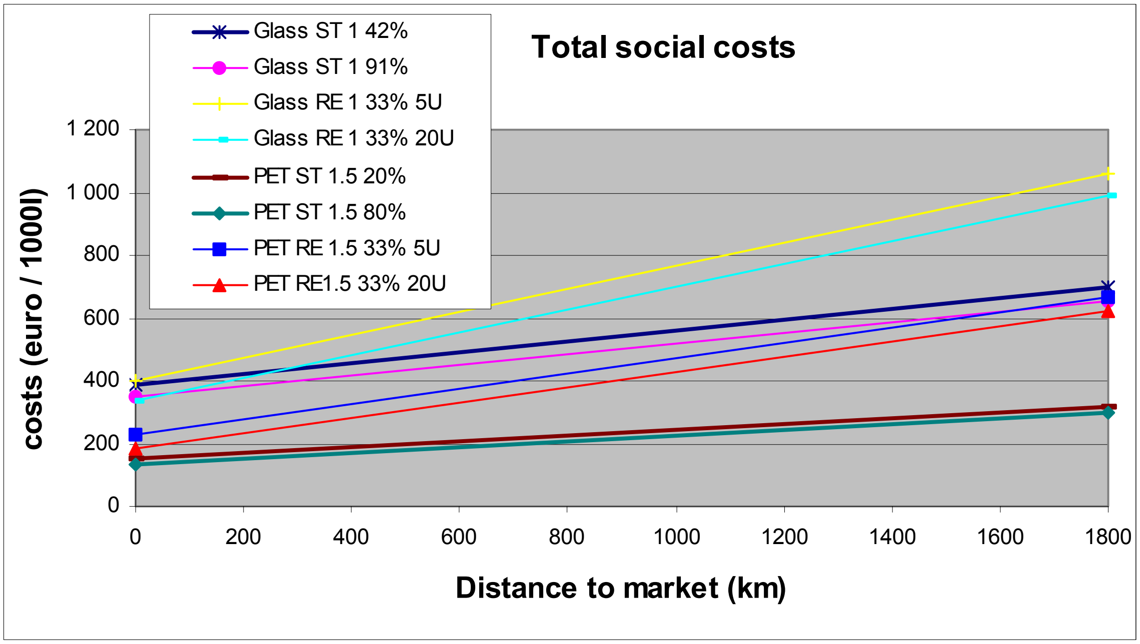
Graph 28 : External costs for refillable and non refillable glass (1 l) and PET (1.5l) beverage packaging



From an <u>external</u> cost perspective,

- For short distribution distances (<193 km)
  - refillable PET is the best option, followed by refillable glass (20U), PET ST, refillable glass (5U) and sensibly higher, ST glass.
- For medium distances (>193 km)
  - PET ST (80% recycling) becomes better than refillable glass (20U) for a distance >193 km
  - PET ST (80% recycling) becomes better than refillable PET (5U) for a distance >413 km
- For long distances
  - ST glass (91% recycling) becomes better than refillable glass (5U) for a distance >1400km
  - refillable PET remains better than ST glass for a distance >1400km
- The external costs are very much dependent on the impacts caused by transport. In particular the toxicity of particulates & aerosols (PM10 equivalent) plays a decisive role

Graph 29 : Total social costs for refillable and non refillable glass (1 l) and PET (1.5l) beverage packaging



For the total social costs :

- ST PET is the best option
- Refillable PET is the second best option
- ST and Refillable glass are less efficient.
- For very long distances (1800 km), ST glass is equivalent to Refillable PET and
- For medium distances (250-300 km), ST glass is better than Refillable glass.

Analysis of the reliability of the conclusions

From the analysis performed, it appears that non-refillable (PET) beverage packaging has the lowest total social cost, mainly due to the lower internal cost.

However the variability of some key parameters influencing the results is high for this case study on beverage packaging : the transport distance (see graph above), the number of uses and the internal cost figures (in particular for the deposit system management). So, as costs and benefits of refillable and non-refillable (PET) beverage packaging are in the same order of magnitude, the observations made from the case study may be non applicable in many individual cases.

Therefore we conclude that there is no generally preferable system between those 2 types of beverage packaging systems.

The merit of this case study is to prove that the internal cost of a refillable system is considerably higher than of a non-refillable and that this more than compensates the refillable's sometimes lower environmental impacts for short distances. Therefore the general rule should not be to encourage refillable beverage packaging. If applied, a policy favouring refillables should be restricted to the cases where the general rule does not apply due to a particular set of key parameters.

5 CONCLUSIONS

5.1 Reservations using those results

When using the results to inform the revision of the recycling targets in the context of the Directive, the following reservations should be taken into account:

- ✓ CBA (cost-benefit analysis) is not yet a mature instrument, specially concerning the economic valuation of the environmental (and social) impacts which must therefore be considered carefully. CBA is a tool to inform the decision-making process only, it is not a substitute for decision-making.
- ✓ High recycling targets can induce high economic costs reflected in the recycling fees (e.g. Green Dot) paid. This influences the price of a packaging material and can therefore induce a shift to other materials which may be more environmentally friendly or less environmentally friendly. It should be noted, however, that :
  - There is no proportionality between recycling costs and the levels of the targets
  - If the recycling fees are also used to finance the treatment of the material that is NOT collected selectively, the induced effect on the material choice will be more limited
- ✓ Some results achieved and conclusions drawn (PET, paper & board[13]) are based upon average market prices of the recycled materials over the last years. These materials can be subject to significant price evolutions, which could change the results of the cost benefit balance.
- ✓ The results achieved should not be interpreted and applied too simplistically. Whilst every effort has been made to take into account variable factors that affect the costs and benefits of the recycling, incineration and landfilling schemes, other local factors not considered may also affect the results (e.g. unavailability of local output market for the recycled materials and therefore long transport distances). Nationally or locally, higher or lower recycling rates than the ones suggested by the results may be preferable in some specific cases.

Despite these reservations, the consultants believe that the study gives a good overall picture of the costs and benefits linked to the investigated targets and that the main driving forces for the

[13] The other ones are based on average value over the last 3 years and are thus more stable

results have been covered. Subsequently, the following conclusions are drawn, but with some caution.

5.2 Conclusions

Conclusion 1 Achieved recycling rates are satisfactory

In 1998 most Member States already achieved the recycling rates set in the Packaging Directive. It seems that all Member States will reach the 25% minimum overall recycling target by 2001 and many will have significantly higher recycling rates and exceed the 45% maximum target set by the Directive. Exceptions are the three Member States that had less stringent requirements (i.e. Greece, Ireland and Portugal). The 15% minimum target for each material will be reached in all concerned Member States, with the exception of plastics for which the target might not be reached in several Member States.

Conclusion 2 Selective collection is better for the society with some notable exceptions

Generally speaking the selective collection of both household and industrial packaging is better for the society than its treatment together with unsorted waste. But there are some notable exceptions (see further conclusions).

Conclusion 3 Household packaging: separate kerbside collection is preferable with notable exceptions

For the selective collection of household packaging very often the separate kerbside collection is preferable above the non separate collection and the bring system (and might thus be considered as the "optimum system" among the modelled systems) due to the higher collection rate. Notable exceptions are :

- Glass should be collected from bottle banks (minimum density : 1 bottle bank per 1000 inhabitants)
- The metals
  - should not be collected selectively in areas where the MSW is incinerated with metals recovery, even if the metals recovered after incineration have a lower quality than the

metals from a selective collection scheme (the quality difference was taken into account in the economic balance).

- may also (i.e. not only kerbside) be collected selectively by a bring system in areas with low population density and landfilling (or incineration without metals recovery) of the MSW

However, as differences are relatively small, this conclusion could possibly be different (i.e. separate kerbside collection could be always preferable) if only the additional cost for separate kerbside collection (cost with metal minus cost without metal) would be taken into account. This has not been investigated.

- There is no evidence to support a mandatory target for the selective collection of Liquid Beverage Cartons, composites and mixed plastics. Again, as the internal costs play a decisive role, this conclusion could possibly be different (i.e. separate collection could be preferable) if only the additional cost for separate kerbside collection (cost with LBC minus cost without LBC) would be taken into account. This has not been investigated
- Plastic bottles should be collected selectively by a bring system in areas where both conditions are fulfilled at the same time :
  - a low population density and
  - the MSW is incinerated with efficient energy recovery

This is summarised below (see Table 26, p. 98).

	Low population density		High population density	
	Landfill	Incineration	Landfill	Incineration
PET bottles	Kerbside	Bring	Kerbside	Kerbside
Steel packaging	Kerbside or bring	No SC	Kerbside	No SC
Al cans	Kerbside or bring	No SC	Kerbside	No SC
Rigid & semi-rigid Al packaging excluding cans	Kerbside or bring	No SC	Kerbside	No SC
Paper and board packaging	Kerbside	Kerbside	Kerbside	Kerbside
LBC	No SC	No SC	No SC	No SC
Mix plastic packaging	No SC	No SC	No SC	No SC

No SC = no selective collection

The following recycling rates are the ones achievable with the those systems (see Table 28, p. 99)

	Low population density		High population density	
	Landfill	Incineration	Landfill	Incineration
PET bottles	70-80%	35-45%	59-69%	59-69%
Steel packaging	15-60%	80%	40-60%	80%
Al cans	31-55%	76%	45-55%	76%
Rigid & semi-rigid Al packaging excluding cans	3-17%	50%	3-8%	50%
Paper and board packaging	61-71%	61-71%	55-65%	55-65%
LBC	0%	0%	0%	0%
Mix plastic packaging	0%	0%	0%	0%

The results were calculated for mechanical recycling. Based on the sensitivity analysis, there are some indications that some alternative routes could be considered as about equivalent to the mechanical recycling : Supercycle, TBI. However these routes have not been investigated deeply so that these conclusions have to be considered very cautiously.

Conclusion 4 Industrial packaging : separate collection is preferable

For industrial packaging the separate collection for recycling is preferable. Notable exceptions are :

- packaging that contained hazardous waste should be collected separately because hazardous waste should not be recycled
- Companies which produce a very small amount of cardboard waste may put the cardboard waste together with the unsorted waste due to the relatively high additional internal cost (additional container and space use).

Conclusion 5 Revised recycling targets

The recycling rates achievable with the "optimum systems" are summarised in the following tables. They are given :

- per Member State and for the EU as a whole (see Table 30, p. 103)

	Global Target Industrial waste		Global Target Household waste		Global target (Industrial + Household waste)	
	Min	Max	Min	Max	Min	Max
Austria	56%	74%	42%	60%	49%	67%
Belgium	54%	70%	42%	65%	48%	67%
Denmark	54%	70%	53%	66%	53%	68%
Finland	57%	73%	35%	48%	48%	63%
France	53%	72%	45%	68%	50%	70%
Germany	56%	72%	45%	71%	51%	**72%**
Greece	53%	70%	39%	52%	46%	61%
Ireland	50%	67%	27%	38%	**40%**	54%
Italy	54%	71%	44%	65%	49%	68%
Luxembourg	54%	70%	46%	66%	50%	68%
The Netherlands	55%	71%	44%	64%	51%	68%
Portugal	57%	75%	46%	64%	47%	65%
Spain	50%	66%	47%	65%	49%	65%
Sweden	59%	76%	44%	54%	52%	66%
United Kingdom	56%	72%	39%	64%	49%	69%
EU	54%	71%	45%	65%	50%	68%

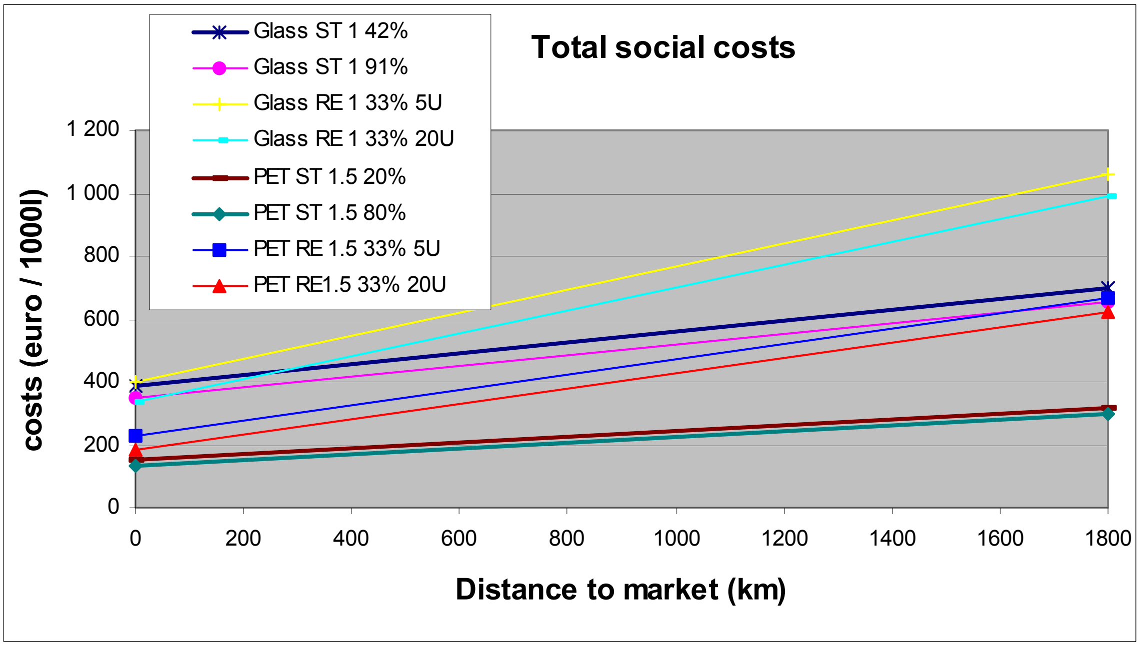
Depending on MS and assumptions, the optimum recycling rate varies from 40% to 72%. There is no uniform optimum recycling rate valid throughout EU. The optimum can vary from MS to MS by as much as 31% (in absolute terms, i.e. from the minimum of the minimum targets to the maximum of the maximum targets).

- per packaging material and for all materials together (see Table 31, p.104)

	Minimum recycling rate	Maximum recycling rate
Plastic	28%	38%
Steel	60%	75%
Aluminium	25%	31%
Wood	47%	65%
Paper & board	60%	74%
Glass	53%	87%
Composites	0%	0%

The value for plastics would be sensibly lower (21-28%) if the plastic waste composition is the one proposed by APME (see sensitivity analysis).

Conclusion 6 Neither refillable nor non-refillable may be considered generally preferable for beverage packaging



From the analysis performed, it appears that non-refillable (PET) beverage packaging has the lowest total social cost, mainly due to the lower internal cost.

However the variability of some key parameters influencing the results is high for this case study on beverage packaging : the transport distance (see graph above), the number of uses and the internal cost figures (in particular for the deposit system management). So, as costs and benefits of refillable and non-refillable (PET) beverage packaging are in the same order of magnitude, the observations made from the case study may be non applicable in many individual cases. Therefore we conclude that there is no generally preferable system between those 2 types of beverage packaging systems.

The merit of this case study is to prove that the internal cost of a refillable system is considerably higher than of a non-refillable and that this more than compensates the refillable's sometimes lower environmental impacts for short distances. Therefore the general rule should not be to encourage refillable beverage packaging. If applied, a policy favouring refillables should be restricted to the cases where the general rule does not apply due to a particular set of key parameters.

Those conclusions do not take into account some possible technical constraints. In some cases those technical constraints could make it undesirable to favour the systems that appear as the preferable ones considering only the environmental and economic aspects. Examples : single trip glass may be acceptable for whiskey for conservation quality and it might be difficult to use PET bottles up to 20 times.

6 GLOSSARY

CBA	:	Cost – Benefit Analysis
EC	:	European Commission
ER	:	Energy Recovery
Grey bag		Bag used for the collection of Municipal solid waste
LBC	:	Liquid Beverage Cartons
MPM	:	Multiple Pathway Method
MS	:	Member State
MSW	:	Municipal Solid Waste
PMC	:	Plastic bottles, Metals and LBC ("Cartons")
WF	:	Weight Factor
PWP	:	Packaging waste producers

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ANNEXES