Topic report 15/2001

Biodegradable municipal waste management in Europe

Part 1: Strategies and instruments
Part 2: Strategies and instruments, Appendices
Part 3: Technology and market issues

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Foreword

The ambitious objective of this report is to assist decision-makers in Europe in their efforts to comply with the demanding targets set out in the EU Landfill Directive by providing background information on applicable strategies and instruments to reduce the quantities of biodegradable municipal waste. It is hoped that the information provided by this report will inspire the responsible authorities to benefit from each other's experience and set up more quickly the national strategies needed for implementation of this Directive.

In this report, the concept of waste minimisation/prevention, a key issue for the EU sustainable development strategy, is followed for such a "difficult" waste stream as biodegradable municipal waste. For many decades it was thought that this kind of waste stream has to be finally disposed in landfill sites, since prevention/recycling schemes cannot be easily applied due to its characteristics (rapid decomposition, release of odours etc.). This perception has led, as stated in our *Environmental Signals 2001* report, to the production and landfill of millions of tonnes of biodegradable municipal waste, which demand large land areas for their disposal and adversely affect environmental quality (greenhouse gas emissions, groundwater pollution etc).

This report is an example of the combination of existing statistical information (data on waste quantities landfilled) with the assessment of more qualitative aspects such as the strategies applicable in countries. This inter-linkage brings to the user a more integrated picture of the magnitude of the problem and the results achieved after the implementation of reduction measures. As a matter of fact, the statistics directly underpinned the development of national strategies and the design of relevant instruments for waste reduction.

We sincerely hope that this example of **best needed information** will increase the added value of EEA products as a substantial input in the decision-making process in Europe and inspire the widespread adoption of creative ideas in the field of waste minimisation and prevention.

Domingo Jiménez-Beltrán

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Introduction

Council Directive 1999/31/EC on the landfill of waste (the landfill directive) places targets on Member States to reduce the quantities of biodegradable municipal waste (BMW) going to landfill. To meet these targets, Member States are obliged to set up national strategies for the implementation of the reduction of biodegradable waste going to landfill.

The principal objective of this report, prepared by the European Topic Centre on Waste (ETC/W) as part of the EEA work programme, is to provide Community-wide information on the current status of biodegradable municipal waste management and the various options available to reduce amounts going to landfill. The report addresses the strategic planning requirements to meet the targets and should be seen as a general guidance tool for EU Member States to assist them with the challenge ahead. It also sets out a methodology and indicators for measuring progress towards the targets set out in the directive and focuses on the attainment of these targets.

Approach

Summary information on biodegradable municipal waste production and management was sought from EEA member countries. This information was used to prepare **BMW Management status sheets** for each country. Information was also sought from each country on the strategies and instruments that are used to encourage the diversion of biodegradable municipal waste away from landfill. Strategies and instruments are presented and discussed for each phase in the production and management of BMW. Case studies are also presented for selected countries and regions (Denmark, the Netherlands and Belgium/Flanders) that have succeeded in diverting more than 80 % of BMW produced away from landfill so that lessons can be learnt from their experience.

Technology and market issues were also addressed with the emphasis being on technologies that are available for diverting biodegradable municipal waste away from landfill and on quality and market issues in relation to products or materials produced through the recovery of biodegradable municipal waste diverted from landfill (a companion report on technology and market issues can be downloaded from www.eea.eu.int).

Key issues

The key issues that ETC/W considers to be of particular importance when planning for compliance with the targets set by the landfill directive include:

The need for good quality and consistent information
A standard approach to tracking progress towards the landfill directive targets is needed. A standard approach to tracking BMW flows in individual countries would also be a useful tool for measuring progress towards the achievement of the targets. However, based on the information supplied by EEA member countries during the course of this project, there are considerable gaps in information at national level. It is therefore important that efforts be continued to establish harmonised systems of data collection and reporting so that reliable waste flow information becomes the norm and not the exception. Ongoing collaboration between ETC/W, Eurostat and the Environment DG will assist this process.

There is also a need for more detailed descriptions of the actual waste types to be considered under the heading ‘biodegradable municipal waste’ as well as guidelines on how to establish the composition of the bagged (mixed) waste component.

Integrated approach to developing national strategies
The experience of countries and regions that have succeeded in diverting large quantities of BMW away from landfill strongly suggests that an integrated package of options is needed at national level to achieve high diversion rates. Countries with high rates of diversion of BMW away from landfill employ a combination of separate collection, thermal treatment, centralised composting and material recycling. Thermal treatment, mainly incineration, is generally used for the treatment of bagged waste while composting, re-use and recycling are used for separately collected wastes such as paper and cardboard, textiles, wood, garden wastes and, to a lesser extent, food wastes. Technologies such as anaerobic digestion, gasification and pyrolysis are in use to a lesser extent, although as the technologies develop their use could become more widespread.

Countries should therefore identify a range of options for managing BMW that is diverted away from landfill which would need to be linked clearly to available markets and outlets for materials diverted away from landfill.

Collection systems
All countries and regions surveyed employ traditional 'bagged waste' collection and separate collection. Generally, traditional 'bagged waste' is either landfilled or incinerated, although some non-thermal treatment also occurs, such as central composting for mass reduction only. The key to achieving both high landfill diversion rates and high re-use, recycling and composting rates (i.e. recovery other than energy recovery) appears to be the provision of widespread separate collection facilities, together with the availability of adequate capacity and markets for the materials thus collected.

Source separation and separate collection should therefore be considered for inclusion in national strategies for meeting the targets set by the landfill directive. This suggestion comes with a note of caution. Each country will need to work out a realistic and achievable target for source separation and separate collection so that it is reasonably confident that the quality of the recovered materials are sufficiently high and that viable markets and outlets exist.

Treatment options
At present, there appears to be a relatively small number of proven treatment options available for BMW diverted away from landfill. The three principal alternatives in use are incineration with energy recovery (mainly of bagged waste), central composting (mainly of garden wastes and, to a lesser extent, food wastes), and material recycling (mainly for paper and cardboard wastes). Some other routes are in use such as anaerobic digestion and use of food waste as animal fodder, but generally, for relatively small quantities of waste. More recent or emerging technologies such as gasification and thermolysis may also play a role in national strategies for the management of BMW. In developing a national strategy to reduce the quantities of biodegradable waste going to landfill, individual member countries should therefore consider the suitability of these options both at national level and at local level. The precise mix of treatment options chosen by a particular country or region will, to a large extent, be based on local or national conditions such as public acceptance of specific technologies.

Availability of markets and other outlets for compost and other end products
When countries are drawing up their national strategies, it is vital that the question of markets and other outlets be addressed. While it is possible to put the infrastructure in place for separate collection and treatment of materials such as paper waste, garden waste and food waste, there is no guarantee that reliable and stable markets will be available for the materials produced. National planners should be fully aware of the importance of establishing and maintaining adequate markets and outlets when drawing up national strategies and plans for the diversion of BMW away from landfill.

Bans and restrictions on landfilling/use of disposal taxes
A key instrument available to individual countries is to impose bans or restrictions on the landfilling of specific waste streams or to tax disposal in order to make recovery a more economically viable option. Several countries have already introduced such restrictions and taxes and the particular design of these instruments very much depends on local and national

social, economic and political conditions. Some countries and regions have adopted or are considering outright bans on the landfilling of either the entire biodegradable fraction of the municipal waste stream while others have introduced a taxation system which increases the cost of landfilling so as to make recovery options more economically viable. Perhaps the optimum approach is to have a combination of progressive restrictions on acceptance of specific waste streams at landfills together with a taxation system that increases the cost of landfilling to a point where it is no longer a financially attractive option. However, whatever approach a country chooses to take, it is essential that alternative routes be identified in advance for waste diverted away from landfill.

Monitoring national strategies for BMW

The landfill directive sets out clear targets and a clear timeframe for reducing the absolute quantity of BMW being consigned to landfill. By basing the target on 1995 production data, a clear roadmap is available for each country, provided that reliable data, or at least agreed data, is available for BMW production in 1995, in accordance with the requirements of the directive. The net impact of future growth in BMW production is that larger quantities of BMW will require treatment by routes other than landfill. It is therefore essential that, as part of its national strategy, each country set up a monitoring and management system that will allow it to track BMW production and management on a continuous basis. Such a system would make the link between production and management of BMW, its subsequent management and the final destination or use of materials, such as compost, produced through its management. Monitoring should be conducted on a continuous basis so that instruments and strategies in use to divert BMW away from landfill are regularly audited and checked for their relative effectiveness and remedial action taken where necessary.

1. Introduction

1.1. Background

Council Directive 1999/31/EC on the landfill of waste (the landfill directive) places targets on Member States to reduce the quantities of biodegradable municipal waste (BMW) going to landfill. To meet these targets, Member States are obliged to set up national strategies for the implementation of the reduction of biodegradable waste going to landfill.

The principal objective of this report, prepared by the European Topic Centre on Waste (ETC/W) as part of the EEA work programme, is to provide Europe-wide information on the current status of biodegradable municipal waste management and the various options available to reduce amounts going to landfill. The report addresses the strategic planning requirements to meet the targets and should be seen as a general guidance tool for EU Member States to assist them with the challenge ahead. It also sets out a methodology and indicators for measuring progress towards the targets set out in the Directive and focuses on the attainment of these targets.

1.2. Terms of reference

The terms of reference for this report are as follows:

- to establish information on existing biodegradable municipal waste management practices in Europe;
- to document the strategic approaches to biodegradable municipal waste management in Europe;
- to provide information on technologies available for diverting biodegradable municipal waste away from landfill;
- to investigate quality and market issues in relation to products;
- to identify key issues and indicators in relation to meeting the targets set by the landfill directive.

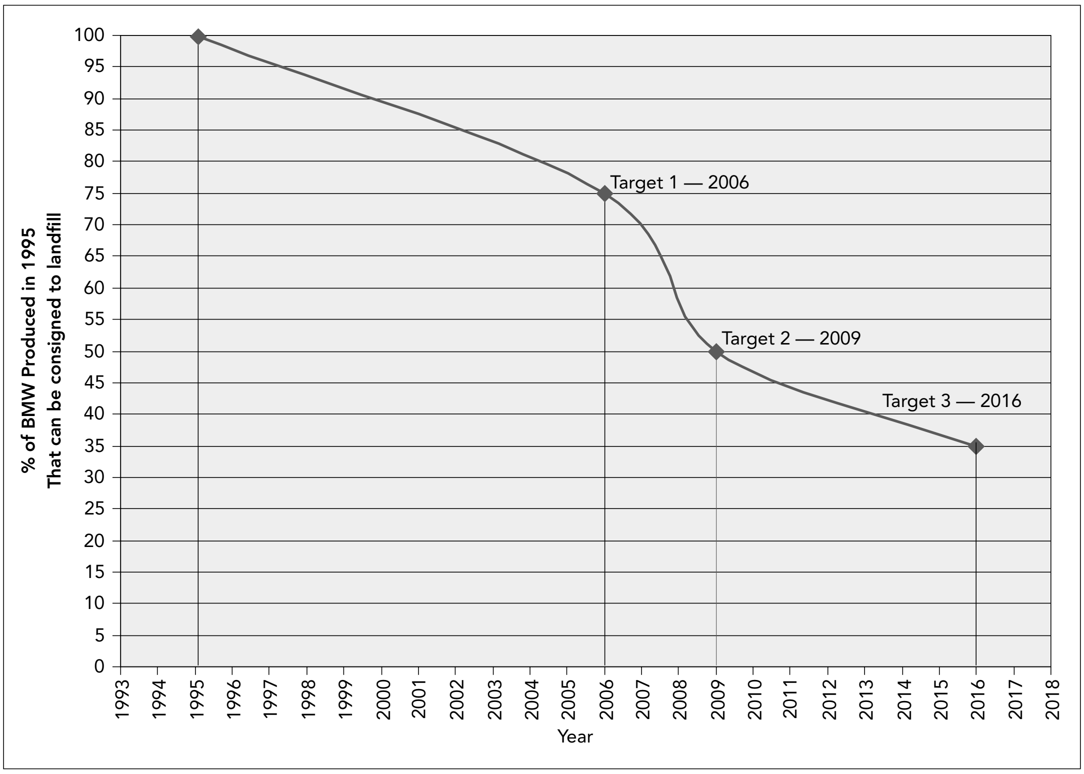
1.3. Context

The targets set by the landfill directive are set out in Article 5 of the directive and require the following:

- not later than **16 July 2006**, biodegradable municipal waste going to landfill must be reduced to **75 %** of the total amount by weight of biodegradable municipal waste produced in 1995 or the latest year before **1995** for which standardised Eurostat data is available;
- not later than **16 July 2009**, biodegradable municipal waste going to landfill must be reduced to **50 %** of the total amount by weight of biodegradable municipal waste produced in 1995 or the latest year before **1995** for which standardised Eurostat data is available;
- not later than **16 July 2016**, biodegradable municipal waste going to landfill must be reduced to **35 %** of the total amount by weight of biodegradable municipal waste produced in 1995 or the latest year before **1995** for which standardised Eurostat data is available.

Member States which in 1995 or the latest year before 1995 for which standardised Eurostat data is available put more than 80 % of their collected municipal waste to landfill may postpone the attainment of the targets set out above by a period not exceeding four years.

Figure 1 **Landfill directive targets**



Note: Countries that landfilled more than 80 % of their municipal waste in 1995 can extend the deadlines shown in the above diagram by four years.

The first target can therefore be extended to 2010, the second to 2013 and the third to 2020. The main implication of the targets is that there is an absolute limit placed on the quantity of biodegradable municipal waste that can be landfilled by specific target dates. This means that if BMW production continues to grow, increasing quantities will need to be diverted away from landfill.

1.4. Approach

Information on biodegradable municipal waste management practices and strategic approaches to the management of biodegradable municipal waste was collected initially from the ETC/W consortium countries and regions (Austria, Denmark, Ireland, Catalonia and Baden-Württemberg) by way of a questionnaire. The intention was to gather sufficient information so that the flow of biodegradable municipal waste (i.e. the amount being produced, how it is collected and how it is managed) could be described for each country and region. Information on strategic approaches to the management of biodegradable municipal waste was also gathered so that the instruments used could be evaluated in respect to their relative success in diverting biodegradable municipal waste away from landfill.

Following analysis of the information received from the consortium countries/regions, a simplified version of the questionnaire was prepared and sent out to each EEA National Reference Centre for Waste (NRC/W) asking for summary information on biodegradable municipal waste flows, along with information on the various strategies and instruments employed for the management of biodegradable municipal waste. Responses were received from all countries surveyed except Iceland, Luxembourg and Spain. Information about Spain was obtained from Junta de Residus, Catalonia (partner in ETC/W consortium). In several cases, the information supplied was insufficient to enable analysis and requests for further information and clarification were issued. Information supplied was then used to prepare a **BMW management status sheet** for each country. These **status sheets** can be downloaded from www.eea.eu.int.

Information on technology and market issues was gathered by designing a pro-forma which was to be completed for each technology type. A companion report on technology and market issues can be downloaded from www.eea.eu.int.

2. Waste definitions and measuring progress towards the targets

2.1. Definition

Municipal waste is defined by Article 2 (b) of the landfill directive as follows:

> 'Municipal waste' means waste from households, as well as other waste, which because of its nature and composition is similar to waste from households.

Biodegradable waste is defined by Article 2 (m) of the landfill directive as follows:

> 'Biodegradable waste' means any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard.

There is no specific definition provided for biodegradable municipal waste, the subject of the targets set by Article 5 of the Directive. However, combining the above definitions provides the following definition:

> 'Biodegradable municipal waste' means biodegradable waste from households, as well as other biodegradable waste, which because of its nature and composition is similar to biodegradable waste from households.

In the EEA Report 'Household and Municipal Waste: Comparability of Data in EEA member countries' (EEA, 2000), the following conclusions were made in relation to the comparability of data on household and municipal waste in Europe:

> 'Total household waste cannot be compared between **all** member countries. This is simply due to the fact that some countries do not provide sufficient information on all waste categories produced by households'.
>
> 'Total municipal waste cannot be compared between **all** member countries due to differences in the kind of waste collected by different municipalities. Data and information on municipal waste must therefore be expected to be incomparable by nature'.

The report goes on to remark, in relation to municipal waste, that 'there has been a general convergence between the various definitions in relation to the **type** of waste that is considered under the heading municipal — waste type is generally understood to mean household-type waste, meaning that industrial-type wastes are not included. Perhaps, in the long term, and in light of the introduction of private collection schemes in many countries, the definition that is provided in the landfill directive is the most practical from the point of view of comparing one country to another as it simply defines municipal waste as household-type waste from any source and is silent on the question of collection'.

There is clearly a problem in comparing historical data on municipal waste arisings in different countries. **This problem also applies to comparing historical data on biodegradable municipal waste arisings**.

Therefore, to attempt to improve the comparability of data collected, the following operational definition was used in this study, which follows the approach adopted in the municipal and household waste survey conducted by ETC/W in 1998:

Biodegradable municipal waste = **bagged** biodegradable municipal waste + **separately collected** biodegradable municipal waste + **bulky** biodegradable municipal waste.

Where:

Bagged biodegradable municipal waste is the **biodegradable fraction of mixed waste** collected door to door on a regular basis (every day, every week, every two weeks etc.) from households

and other sources such as commerce and trade activities, office buildings, institutions (schools, government buildings etc.) and small businesses.

The biodegradable fraction of mixed waste is the food, garden, paper and paperboard, textiles, wood and other miscellaneous biodegradable content of the waste collected.

Separately collected biodegradable municipal waste is food, garden, paper and paperboard, textiles, wood and other miscellaneous biodegradable wastes **separately collected** from households **and** other sources such as commerce and trade activities, office buildings, institutions (schools, government buildings etc.) and small businesses. Separately collected waste also includes those fractions mentioned above which are delivered to civic waste facilities, bring banks, recycling centres etc.

Bulky biodegradable municipal waste is the biodegradable fraction of bulky waste collected from households and other sources such as commerce and trade activities, office buildings, institutions (schools, government buildings etc.) and small businesses. This includes bulky biodegradable waste delivered to civic waste facilities, bring banks, recycling centres etc.

The biodegradable fraction of bulky waste is made up of materials such as wooden furniture etc. Bulky garden waste is reported under the heading 'separately collected food and garden waste'.

2.2. Establishing a baseline for the targets

The baseline against which the targets are to be measured is 1995 or the latest year before 1995 for which standardised Eurostat data is available. There is an immediate problem in setting a baseline for individual countries because countries did not report biodegradable municipal waste quantities for 1995 or earlier years. In addition, as stated above, data on municipal waste must, by its nature, be expected to be incomparable. However, Eurostat has conducted a preliminary evaluation of its standardised data on household and municipal waste and has developed a set of statistics for EEA member countries. The preliminary data is presented in Table 1, along with supporting footnotes and remarks.

Eurostat baseline data for BMW landfilled Table 1

Country	Year	Managed MW [1)]	Managed BMW [2)]	Separately collected and recovered BMW [3)]	MW incinerated	BMW landfilled [4)]
		Ktonnes	Ktonnes	Ktonnes	Ktonnes	Ktonnes
Austria [5)]	1995	2644	1745	791	431	523
Belgium	1995	5014	4312	425 [6)]	1490	2397
Denmark	1995	2591 [7)]	2560	641	1466	453
Finland	1994	2100 [7)]	1890	0	50	1840
France	1995	34700	27760	220	10352	17188
Germany	1993	40017	28700		8552	20148
Greece	1990	3000	2688	0	0	2688
Ireland	1995	1550	1073	60	0	1013
Italy [8)]	1996	24524 [7)]	21655		1572	20083
Luxembourg	1995	278	160	0	126	34
Netherlands	1994	8161 [7)]	7280	2523	2192	2565
Portugal	1995	3884	3301		6	3295
Spain	1995	14914	11633	2117	693	8823
United Kingdom	1995	29000 [9)]	21460		2200	19260
Sweden	1994	3200	2656	400	1300	956

1) Municipal waste managed: MW generated (=collected) + import — export.
2) Biodegradable municipal waste is calculated from 'Municipal waste managed' minus the 'non-biodegradable' fraction. These waste-fractions are calculated with the help of the given composition of municipal waste. The non-biodegradable fractions concerned here are glass, plastic and metal. (In some cases, plastics may be considered to be biodegradable). Figures on the composition of municipal waste are not always from the same year as the waste-figures, or on household waste instead of municipal waste. For municipal waste incinerated no estimations are made for the biodegradable and non-biodegradable fraction. This could be done with the figures on the composition of municipal waste.
3) Food and garden waste, paper, textile, wood, oil and fat.
4) Calculated as follows: managed BMW — separately collected and recovered BMW — incinerated MW.
5) Household waste.
6) Different years (1995 or <) because of separate data provision of the different regions (Flanders, Walloon, Brussels).
7) Sum of treatment and disposal of municipal waste.
8) Latest year before 1995 is 1985.
9) Municipal waste generated.

The ETC/W, as a result of the surveys conducted for this project, has also developed baseline data for each country where sufficient data was provided. Where data has not been reported for 1995, the data for the year closest to 1995 has been chosen. This data is presented in Table 2.

Table 2 ETC/W baseline data for BMW landfilled

Country/region	Year	MW produced	BMW produced	BMW landfilled
		Ktonnes	Ktonnes	Ktonnes
Austria	1995	2644	1495	302
Belgium (Flanders)	1995	2890	1671	623
Denmark	1995	2787	1813	205
Finland	1994	2100	1664	1 085
France	1995	36200	15746	5 988
Germany	1993	43486	12000 1)	N/A
Germany (Baden-Württemberg)	1995	18300	5859	2 502
Greece	1997	3900	2613	2 324
Iceland	1995	N/A	N/A	N/A
Ireland	1995	1503	990	903
Italy	1996	25960	9170	6 821
Luxembourg	1995	N/A	N/A	N/A
Netherlands 3)	1995	7105	4830	1 365
Norway	1995	2722	1572	1 069
Portugal	1995	3340	N/A	N/A
Spain 2)	1996	17175	12196	N/A
Spain (Catalonia)	1995	2834	1985	1 481
Sweden	1998	4000	N/A	N/A
United Kingdom 4)	1996/97	25980	16366	14 675

1) Biodegradable waste from households.
2) Plan Nacional De Residuos Urbanos (2000–06).
3) Figures relate to waste from households only.
4) England and Wales only.
N/A: Information not available

2.3. Measuring progress towards the targets

An agreed approach is required for measuring progress towards the targets set by the landfill directive for biodegradable municipal waste. This requires agreement on the following items:

- the definition of biodegradable municipal waste — a common understanding of the term is required;
- a set of baseline figures against which progress will be measured; and
- a standard approach for tracking changes in biodegradable municipal waste produced.

2.3.1. Definition

The operational definition provided in Sub-Section 2.1 above is recommended for the purpose of gathering data on biodegradable municipal waste. There is, however, a requirement for more detailed descriptions of the actual waste types to be considered as well as guidelines on how to establish the composition of the bagged (mixed) waste component. However, the approach recommended is considered to be reasonably pragmatic and workable.

2.3.2. Baseline data for 1995

The data set out in Table 3 below is presented as a proposed operational baseline for biodegradable municipal waste production in 1995, subject to the agreement of each EEA member country and Eurostat. These are based on the operational definition set out above and have been calculated from the data supplied to ETC/W by each member country. Where a member country supplied insufficient data, the Eurostat estimate (see Table 1 above) was used.

Proposed Baseline data for BMW produced and landfilled in 1995 (1) Table 3

Country/region	Year	MW produced	BMW produced	BMW landfilled
		Ktonnes	Ktonnes	Ktonnes
Austria	1995	2 644	1 495	302
Belgium 1)	1995	5 014	4 312	2 397
Belgium (Flanders)	1995	2 890	1 671	623
Denmark	1995	2 787	1 813	205
Finland	1994	2 100	1 664	1 085
France	1995	36 200	15 746	5 988
Germany 1)	1993	40 017	28 700	20 148
Germany (Baden Württemberg)	1995	18 300	5 859	2 502
Greece 1)	1990	3 000	2 688	2 688
Iceland	1995	N/A	N/A	N/A
Ireland	1995	1 503	990	903
Italy	1996	25 960	9 170	6 821
Luxembourg 1)	1995	278	160	34
Netherlands 3)	1995	7105	4830	1 365
Norway	1995	2 722	1 572	1 069
Portugal 1)	1995	3 884	3 301	3 295
Spain 1)	1995	14 914	11 633	8 823
Spain (Catalonia)	1995	2 834	1 985	1 481
Sweden 1)	1994	3 200	2 656	956
United Kingdom 3)	1996/97	25 980	16 366	14 675

1) Source: Eurostat.
2) Figures relate to waste from households only.
3) England and Wales only.
N/A: Information not available

2.3.3. Tracking changes in BMW production and management

An agreed approach to tracking changes in the quantities of biodegradable municipal waste produced and the fate of the waste is required so that a consistent approach is adopted within the European Community. An approach based on the Summary Flow Sheet used to gather data during the course of this study is recommended.

There is, however, a need for further guidelines on waste types to be included under the main headings (food, garden, paper etc.) and guidelines on the conduct of waste composition analysis of the mixed municipal waste stream.

(1) Where figures were not available from the ETC/W returns, the relevant Eurostat data was used.

3. Existing management practices in Europe

3.1. Introduction

This section provides an overview of:

- biodegradable municipal waste arisings in Europe (2);
- existing biodegradable municipal waste (BMW) management practices in Europe; and
- projections of biodegradable municipal waste arisings for each country.

Landfill of BMW varies widely from one country to another. This means that some countries, such as Denmark, Austria and the Netherlands, have already reduced their reliance on landfill to the point that the targets set by the Directive have effectively been met. Other countries, such as Italy, the United Kingdom and Ireland, still send most of their BMW to landfill and have a long way to go to reach the targets.

It is therefore important to document the practices in countries with low levels of BMW going to landfill, so that other countries can benefit from this information when formulating their own strategies. However, it is also important to note that there is little room for complacency in countries that currently divert large quantities of biodegradable municipal waste away from landfill. Even relatively modest growth in the production of biodegradable municipal waste between now and 2016/2020 will require planning for significant additional 'landfill diversion' capacity above that which is currently available (3).

3.2. Overview

Table 4 provides an overview of BMW production in the various countries and regions that supplied information. Total tonnage produced in 1995 (the baseline year for the landfill directive) and per capita production are provided. As can be seen, per capita production ranges from 0.16 tonnes per person for Italy up to 0.36 tonnes per person for Norway. Per capita production of BMW is a key indicator for tracking progress towards the achievement of the landfill directive targets, both at national and European level. Average production per capita for these countries is 0.30 ± 0.06 tonnes per annum. While there is a relatively wide range between the highest and lowest values, the overall variation is 20 % of the average, which suggests, overall, that variations between different countries may not be so high. This is probably because biodegradable municipal waste is, generally, waste produced from the daily or routine activities of households and businesses which may not vary that significantly from one country to another. However, in order for per capita production figures to be a truly reliable comparative indicator, each country should use the same definition for both municipal waste and biodegradable municipal waste, which is currently clearly not the case.

(2) Europe' in this report means 'EEA member countries'.
(3) This, of course, could be offset by successful waste prevention and minimisation programmes; however, success to date in relation to waste prevention in the municipal sector has been limited, with gross quantities of municipal waste continuing to rise in most countries.

Summary of BMW production in countries and regions surveyed Table 4

Country/region	BMW produced in 1995 (tonnes)	BMW production/capita (tonnes/person)
Austria	1 495 000	0.19
Belgium (Flanders)	1 671 108	0.28 [1)]
Denmark	1 813 283	0.35
Finland (1994)	1 664 000	0.33
France	15 746 000	0.27
Germany (1993)	28 700 000	0.35
Greece (1997)	2 613 000	0.25
Ireland	990 242	0.27
Iceland	N/A	N/A
Italy (1996)	9 170 530	0.16
Luxembourg	N/A	N/A
Netherlands [3)]	4 830 000	0.31
Norway	1 571 607	0.36
Portugal	N/A	N/A
Spain [2)] (1996)	12 196 099	0.31
Spain (Catalonia)	1 984 912	0.32
Sweden	N/A	N/A
United Kingdom [4)] (1996/97)	16 366 000	0.31

1) Population of Flanders at 1 January 1999 = 5 926 838.
2) Plan Nacional De Residuos Urbanos (2000–2006).
3) Figure relates to waste from households only.
4) England and Wales only.
N/A: Information not available

The management of BMW in the countries and regions surveyed is summarised in Figures 2 and 3. Figure 2 presents an overview, for the most recent year for which reliable data is available, of BMW collection practices in the various countries and regions surveyed. As can be seen, the percentage of BMW separately collected ranges from nearly 70 % in Flanders to 5 % in Catalonia. While there would appear to be relatively low variation in the quantities of BMW produced per capita, as illustrated in Table 4 above, there is considerable variation in the collection of BMW. Flanders, Austria, the Netherlands, Denmark and Norway, all report over 30 % separate collection of BMW.

Figure 3 and Table 5 provide an overview, for the most recent year for which reliable data is available, of BMW waste management practices in the countries and regions surveyed. This gives an indication of the range and extent of practices applied. For instance, countries and regions such as Denmark, the Netherlands, Flanders and Austria, which have low reliance on landfill, employ a mixture of incineration, composting and recycling to treat BMW produced. Reliance on landfill for the treatment of BMW ranges from as low as 5 % in Denmark to over 80 % in the United Kingdom and Ireland.

Figure 2 **Collection practice in countries and regions surveyed**

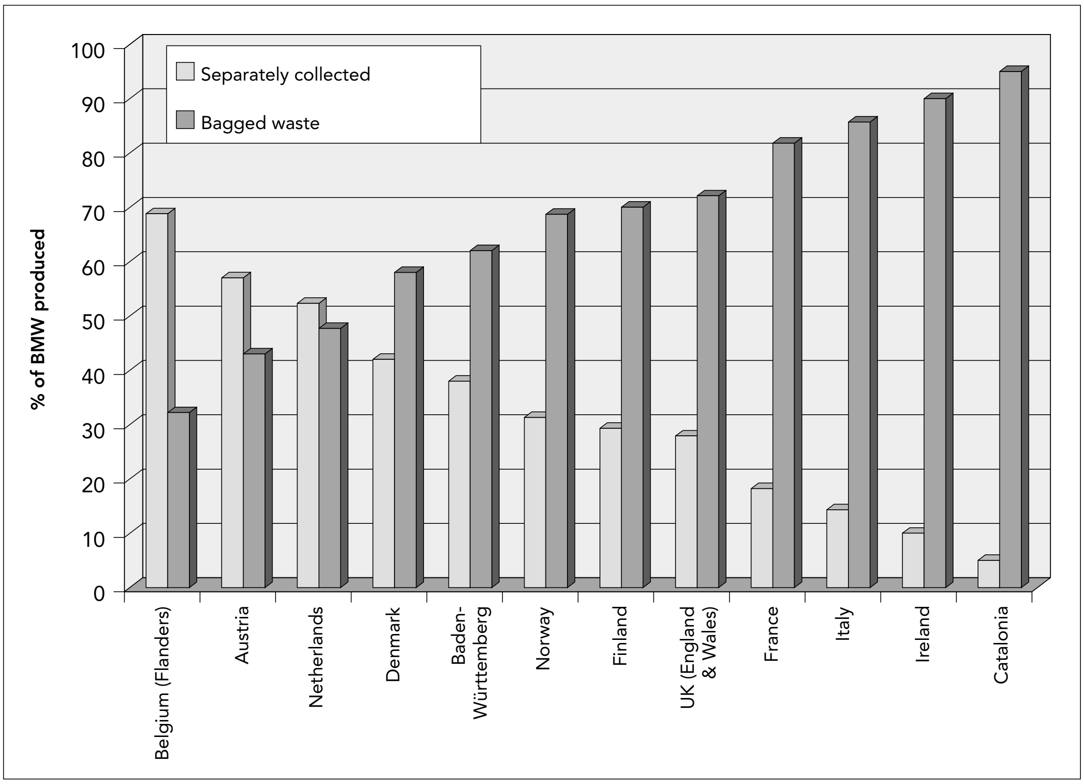
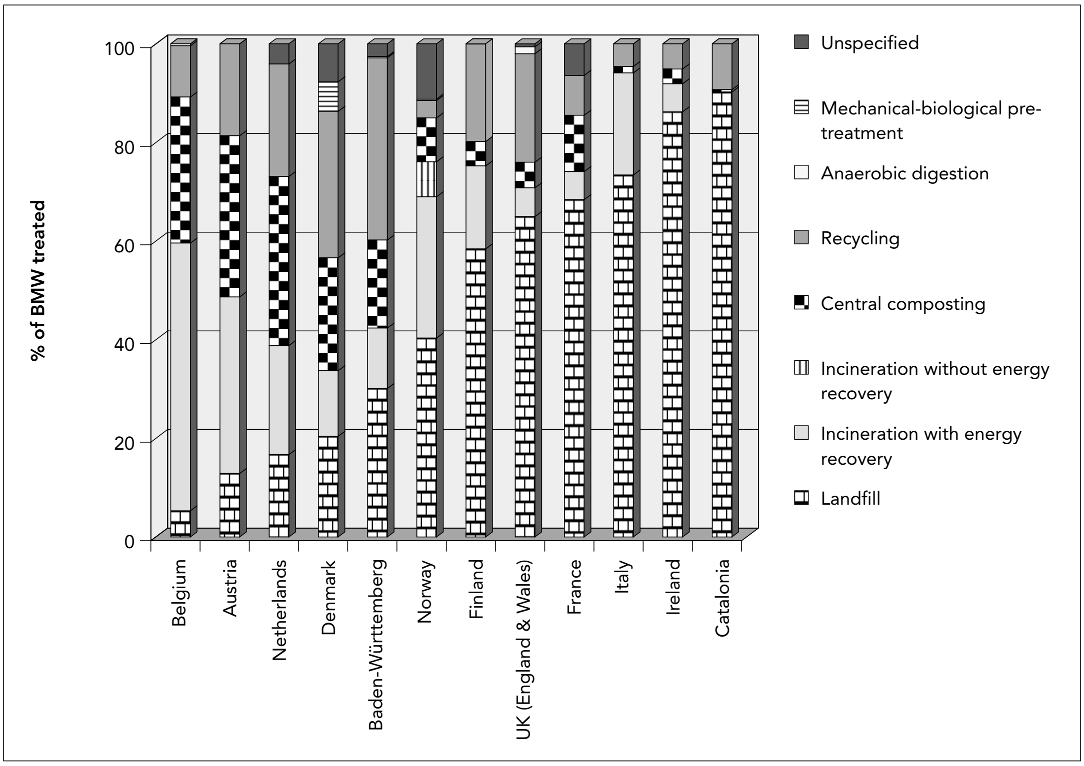


Figure 3 **Management of BMW in countries and regions surveyed**



Management of BMW in countries and regions surveyed — Table 5

	BMW management routes (% of total BMW produced)							
	Landfill	Incineration with energy recovery	Incineration without energy recovery	Central composting	Recycling	Anaerobic digestion	Mechanical-biological pre-treatment	Unspecified
Austria (1996)	20.4	13.3	0	22.9	29.7	0	6.0	7.7
Belgium (Flanders) (1998)	16.7	22.1	0	34.3	22.8	0	0	4.1 [1)]
Denmark (1998)	5.3	54.3	0	29.6	10.4	0.4	0	0
Finland [2)] (1997)	64.9	5.8	0	5.2	22.0	1.4	0	0.6
France [3)] (1998)	40.3	28.6	7.1	8.9	3.5	0.3	0	11.2
Germany	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Germany (Baden-Württemberg) (1998)	30.2	12.3	0	17.9	37.1	0	0	2.6 [4)]
Greece	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iceland	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ireland (1998)	90.3	0	0	0.5	9.3	0	0	0
Italy (1997)	68.4	5.7 [5)]	0	11.4	8.1	0	0	6.4
Luxembourg	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Netherlands (1998)	13.1	36.5	0	33.3	19.0	0	0	0
Norway (1997)	59.0	17.0	0	5.0	20.0	0	0	0
Portugal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Spain	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Spain (Catalonia) (1998)	73.4	20.7	0	1.3 [6)]	4.6	0	0	0
Sweden	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
United Kingdom [7)] (1998/99)	86.2	5.7	0	3.0	5.1	0	0	0

1) This figure refers to the percentage of BMW which is managed through re-use.
2) 0.58 % refers to 10,320 tonnes of Packaging and Wood waste separately collected in 1997, for which storage is the only known management route.
3) Waste management routes for France only account for 88.8 % of the total BMW produced. The remaining 11.2 % is accounted for by separately collected garden waste, the management route of which is unspecified or unknown.
4) This figure may include a fraction managed by anaerobic digestion.
5) This figure refers to incineration with/without energy recovery.
6) This figure is accounted for by 0.43 % central composting and 0.79 % mass composting.
7) England and Wales only.
N/A: Information not available

The three principal routes for diverting BMW away from landfill are incineration with energy recovery, central composting and recycling. Countries and regions with low landfill rates for BMW tend to employ a mixture of incineration and central composting, along with recycling, mainly of paper.

3.3. BMW management status sheets

Completed summary flow sheets for each country can be downloaded from www.eea.eu.int. Information supplied varied significantly from country to country with some countries supplying limited information. A management status sheet was prepared for each country and region that supplied sufficient information for this to be done. These sheets can also be downloaded from www.eea.eu.int. Each sheet contains summary information on:

- existing collection and management practices;
- future projections of BMW arisings;

- maximum quantity that can be landfilled; and
- quantities requiring diversion from landfill based on future projections.

Projections were estimated for the following scenarios:

- 1 % annual growth;
- 2 % annual growth;
- 3 % annual growth;
- average projected growth in GDP between 1995 and 2015; and
- average projected growth in private consumption between 1995 and 2015.

Data for average projected growth in GDP and private consumption was abstracted from a baseline scenario developed by the Dutch Environmental Research Institute (RIVM) and used previously by the Topic Centre for developing projections of household, paper and glass arisings (European Environment Agency, 1999).

3.4. Key information gaps

A fundamental requirement for the preparation of a strategy for meeting the targets set out in the landfill directive is a comprehensive understanding of the quantities of BMW being produced and its fate, i.e., what happens to it once it has been collected for management. The summary sheets prepared for data collection within this project provide a guideline for the type of information required to establish this information. As stated above, information supplied varied significantly from country to country with some countries supplying limited information. This suggests that significant effort is required on the part of certain Member States to establish the basic information on BMW production and management required to prepare a meaningful strategy.

3.5. Future projections and implications

Strategic planning for the landfill directive requires an appreciation of the possible implications of growth in BMW production during the lifetime of the Directive. Several scenarios have been considered for each country, as set out above, with the results presented in the BMW Management Status Sheets, which can be downloaded from www.eea.eu.int. As with all projections into the future, the results must be treated with a degree of caution; however, they give an indication of the types of challenges various Member States might face in the coming years.

As an example, Table 6 presents an overview of projected quantities for each country for the year 2016, based on the assumption that BMW quantities will grow in line with projected growth in private consumption. As can be seen, the key impact will be a significant increase for all countries in the quantity of BMW requiring diversion away from landfill, because the landfill directive imposes an absolute restriction on the quantity of BMW that can be landfilled. For instance, countries that currently landfill relatively modest quantities of BMW, such as Denmark and the Netherlands, may have to plan for a significant increase in the quantities of BMW requiring treatment by alternative routes to landfill, particularly if it is planned to maintain low landfilling rates. Figure 4 illustrates this point by providing a comparison between quantities currently diverted away from landfill (where available) and quantities that will require diversion away from landfill in the event that future growth in BMW is in line with growth in private consumption.

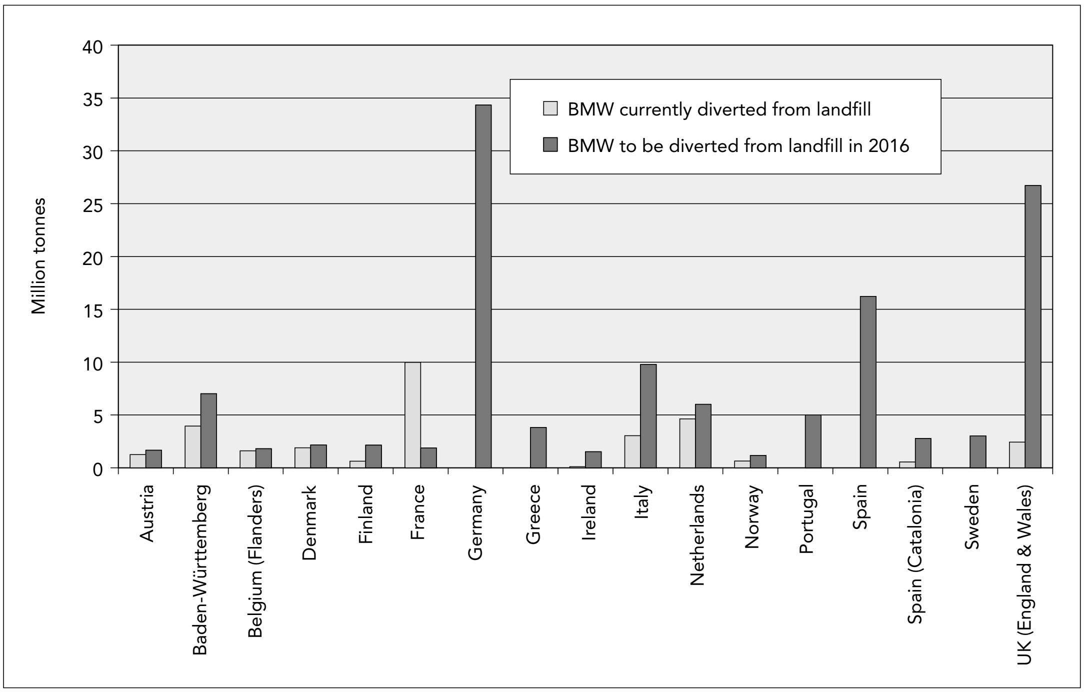
Implications of growth in BMW up to 2016 Table 6

Country/region	BMW baseline — 1995	Projected quantity produced in 2016	Maximum quantity to landfill in 2016 1)	Quantity to be diverted from landfill in 2016 2)
	(Million tonnes)			
Austria	1.495	2.17	0.523	1.647
Belgium (Flanders)	1.671	2.39	0.585	1.805
Denmark	1.813	2.79	0.635	2.155
Finland	1.664	2.72	0.582	2.138
France	15.746	24.36	5.511	18.849
Germany	28.7	44.381	10.045	34.336
Germany (Baden Württemberg)	5.859	9.060	2.05	7.01
Greece	2.688	4.756	0.941	3.815
Iceland	N/A	N/A	N/A	N/A
Ireland	0.990	1.87	0.346	1.524
Italy	9.170	12.984	3.209	9.775
Luxembourg	0.16	N/A	0.056	N/A
Netherlands	4.830	7.699	1.691	6.008
Norway	1.572	1.712	0.5502	1.162
Portugal	3.301	6.160	1.155	5.005
Spain	11.633	20.293	4.071	16.222
Spain (Catalonia)	1.985	3.46	0.695	2.765
Sweden	2.656	3.948	0.9296	3.0184
United Kingdom	19.66	33.60	6.881	26.719

1) 35 % of the Baseline.
2) Projected quantity produced — maximum quantity permitted to landfill.
N/A has been inserted where no figure for private consumption was available

Clearly, any increases in BMW production during the lifetime of the Directive will have profound effects on the requirement for treatment routes other than landfill. A fundamental part of each countries strategy should be a comprehensive analysis of future trends in BMW production between now and 2016 (or 2020 in the case of countries seeking the four year extension) so that adequate capacity can be planned well in advance of requirements. National strategies will also need to be sufficiently flexible to respond to changes such as economic and demographic changes that may have an effect on the quantities of BMW produced. This will require, among other things, the development of implementation plans and on-going review of such plans.

Figure 4 **Estimated current quantities of BMW being diverted from landfill and estimated quantities requiring diversion by 2016**



Note: Figures for BMW currently diverted from landfill not available for Germany, Greece, Portugal, Spain or Sweden.

4. Strategies and instruments for diverting BMW away from landfill

4.1. Introduction

The typical flow of biodegradable municipal waste is illustrated schematically in Figure 5. It can be broken down into four specific phases:

Phase 1 — production
Phase 2 — presentation ([4]), collection, transfer and movement
Phase 3 — treatment
Phase 4 — end-use/final destination (beneficial use or disposal)

When considering the various strategies and instruments available to assist in the diversion of biodegradable municipal waste (BMW) away from landfill, each phase requires analysis because interventions across the board from production to final destination will probably be required in order to achieve the required landfill diversion rates. It is also useful to consider at what point in the waste chain a particular instrument or strategy fits so that each part of the waste chain is considered and addressed when preparing a strategy for diversion of waste away from landfill.

Phase 1 is the production of biodegradable municipal waste. In many ways, this is the most difficult phase to tackle as it requires the implementation of successful waste prevention and waste minimisation measures. However, it also requires the development of a comprehensive understanding of the composition of the waste stream so that, for instance, it is known what proportion of the waste stream consists of food waste, paper, cardboard, newspaper etc. and how seasonal and other factors effect composition. Strategies and instruments relevant to Phase 1 therefore include waste prevention initiatives such as public education programmes, school campaigns, consumer awareness programmes, waste reduction initiatives and re-use programmes, and waste management initiatives such as waste composition surveying.

Phase 2 involves the presentation, collection and transfer/movement of waste. Many countries have laws in place which enable municipal authorities to specify how waste can be presented for collection, for instance, the size and type of receptacle to be used. Restrictions can also be placed on the types of waste acceptable for collection. There is considerable scope, therefore, for controlling what enters the waste chain by controlling how waste is presented for collection. Phase 2 is of central importance in relation to the diversion of waste away from landfill because the manner in which waste is collected has a profound effect on the treatment options available.

Phase 3 consists of the various treatment options available for managing the biodegradable fraction of municipal waste. As stated above, the manner in which this waste fraction is collected determines, to a large extent, the options which are available to deal with this waste stream. Key strategies and instruments relevant to Phase 3 include those that are designed specifically to divert waste away from landfill, such as bans or restrictions on the type of waste that can be landfilled and waste taxes such as landfill taxes.

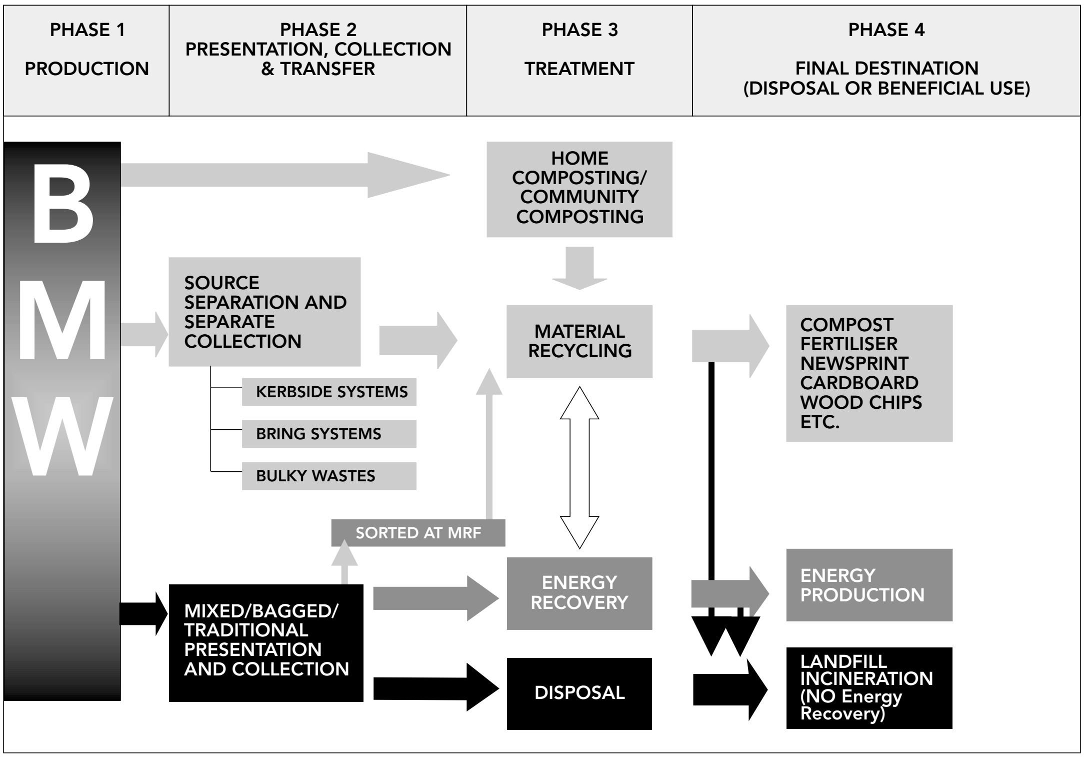
Phase 4 is the final destination or end use of the material. Key instruments here relate to ensuring that markets and outlets are available for materials diverted from landfill to various recovery routes.

Table 7 provides an overview of the strategies and instruments reported by the countries examined to assist in diverting BMW away from landfill. These instruments include separate collection, incinerating a significant proportion of the biodegradable municipal waste

(4) Presentation means, in this context, **preparation for collection** and is the step in the waste chain between generation and collection of waste with specific requirements, e.g. use of specific types of containers, pre-sorting of wastes.

fraction, banning or restricting the landfilling of BMW, fiscal instruments and home composting. It is evident that countries that are presently diverting significant quantities of BMW away from landfill, are not reliant on just one instrument but have adopted a range of instruments in order to maximise landfill diversion rates.

Figure 5 **Summary flow chart for biodegradable municipal waste**



Strategies and instruments in use Table 7

Instrument/ country	Separate collection [1]	Significant quantities incinerated (> 20 %)	Tax on waste going to landfill	Ban on landfilling of BMW	Other fiscal instruments	Home composting
Austria	√	X	√	X	√ [2]	√
Belgium (Flanders)	√	X	√	√ [3]	√ [4]	√
Denmark	√	√	√	√	√ [5]	√
Finland	√	X	√	To be introduced on 1/1/05	√	√
France	√	X	√	To be introduced in 2002	N/A	N/A
Germany	√	√ [6]	X	To be introduced in 2005	X	√
Baden-Württemberg	√	X	X	To be introduced in 2005	X	√
Greece	√	X	X	C	N/A	N/A
Iceland	N/A	N/A	N/A	N/A	N/A	N/A
Ireland	√ [7]	X	X	X	X	√ [8]
Italy	√	X	√	To be introduced in 2001	N/A	√
Luxembourg	N/A	N/A	N/A	N/A	N/A	N/A
Netherlands	√	√	√	√	N/A	N/A
Norway	√	X	√	To be introduced on 1/1/01 [8]	√ [9]	N/A
Portugal	√	N/A	X	X	N/A	N/A
Spain	√	N/A	N/A	N/A	N/A	N/A
Catalonia	√	√	X	X	√ [10]	N/A
Sweden	√	√	√	To be introduced in 2005	√ [11]	√
UK (England & Wales)	√	X	√	To be introduced	X	√

1) The quantities and fractions being separately collected vary significantly between countries.
2) The cost of collection from households is based on the quantity collected. Thus there are reduced costs for those households that carry out home composting.
3) Ban on the landfilling of separately collected paper and paperboard, separately collected food and garden waste and municipal waste from households.
4) There are higher collection costs for unsorted waste.
5) Some municipalities charge less where home composting is carried out.
6) Exact quantity of BMW incinerated is not known but is expected to be greater than 20 %.
7) Pilot scale at present.
8) One county has introduced this since 1995.
9) Charges for waste collection from households are based on quantities collected. There are lower collection fees for those that carry out home composting.
10) Subsidies are available for the promotion of separate collection. There are also fiscal measures to discourage the landfilling of waste.
11) Investment grants are provided for the development of new biological treatment plants. There are also reduced collection fees for households that carry out home composting or households that participate in communal composting schemes.

(Key √ — in use; C — not in use; N/A — no information available)

In developing a strategy, it is important to examine each link in the waste chain and to consider at what point particular strategies and instruments might apply. In addition, it is important to examine the flow of biodegradable waste through the waste chain and to consider how the application of a specific instrument may influence decisions or options in subsequent phases.

Table 8 lists typical strategies and instruments and links them to the particular phases in the waste chain (see Figure 5). As can be seen in a number of the cases, some of the instruments have a role to play in each of the phases e.g., public education, fiscal measures and producer responsibility initiatives and obligations, whereas others are only applicable to a particular phase, for example, waste prevention and minimisation.

Table 8 **Strategies and instruments appropriate to different phases**

Instrument/phase	Phase1 Production	Phase 2 Presentation, collection, transfer & treatment	Phase 3 Treatment	Phase 4 Final destination (disposal or beneficial use)
Waste prevention and Minimisation	√			
'Greener' shopping	√			
Home composting	√			
Public education	√	√	√	√
Fiscal measures	√	√	√	√
Producer responsibility initiatives and obligations	√	√	√	√
Use of presentation by-laws		√		√
Requirement for separate collection		√	√	√
Significant quantities incinerated			√	
Ban on landfilling of BMW		√	√	√
Ban on landfilling of specific BMW fractions		√	√	√
Waste taxes		√	√	√
Identification and development of end markets		√	√	√

Strategies and instruments appropriate to each phase are discussed in the following sub-sections. A number of case studies are also presented in this section for countries and regions that have succeeded in diverting large quantities of BMW away from landfill.

4.2. Phase 1 — production

Phase 1 of the waste chain relates to the production of biodegradable municipal waste. As the quantity produced increases, the management responses required become more critical. Thus, in the long term, one of the most important instruments that can be used to reduce the quantity of BMW which is consigned to landfill is preventing or minimising the generation of this waste in the first instance. BMW waste prevention and minimisation initiatives apply mainly to the paper and cardboard fraction with home composting the main route through which food and garden waste can be prevented from entering the municipal waste stream.

Waste prevention and minimisation sits at the top of the EU waste hierarchy as being the most desirable option for dealing with waste. A number of different methods can be employed to encourage the general public and commercial enterprises to reduce the amount of waste that they produce. Such measures include:

- consumer awareness: encouraging individuals to become 'greener' shoppers, e.g. only buy what you need, buy loose products if possible, choose products which have minimal packaging, buy concentrated products as they use less packaging, choose products in reusable or returnable packaging and products that come in recycled or recyclable materials;
- public education: Public education is a very important measure to be employed to encourage the general public to reduce the quantity of waste that they produce.
- Separation at source: Encouraging householders to separate their waste into the various different fractions, e.g. paper and paperboard, food and garden waste, textiles and wood;
- home composting: Encouraging householders to home compost the relevant biodegradable fractions of their municipal waste;
- fiscal instruments: The use of fiscal measures to encourage householders to reduce the quantity of waste that they produce has proven to be very beneficial. These have included charges for waste collection and treatment based on the quantity of waste put out for collection;

- producer responsibility initiatives and obligations: These are initiatives or obligations undertaken by those involved in the manufacture, distribution and sale of products. These can be effective tools for making producers take greater responsibility for goods at the end of their lives. These initiatives can include reductions in the quantity of packaging required, reductions in the polluting potential of the packaging i.e., reductions in the heavy metal content of the packaging or increasing the quantity of recycled material used in the products. Producer responsibility programmes can be either voluntary agreements between public authorities and bodies representing waste producers such as trade associations or mandatory measures imposing obligations on specific producers.

Most countries appear to prefer the use of voluntary agreements. In England and Wales, for instance, the Government has been working with the Newspaper Publishers Association to increase the recycled content of newsprint which in 1999 was approximately 54 %. The newspaper publishers have agreed to commit themselves to the following targets: 60 % recycled content by the end of 2001, 65 % recycled content by the end of 2003 and 70 % recycled content by the end of 2006. These targets will be subject to review in 2001 and 2003 (DETR, 2000). Many of the agreements reached in Member States to facilitate progress towards the targets set by the Packaging Directive are voluntary agreements, backed up with the promise of mandatory measures being introduced in the absence of progress.

While more difficult to tackle than other phases in the waste chain, national strategies should address waste prevention and minimisation as a key area for action and countries should put in place measures to encourage prevention and minimisation as an integral part of the strategy.

4.3. Phase 2 — presentation, collection and transfer/movement

4.3.1. Overview

Phase 2 relates to the presentation, collection and transfer/movement of waste and is, perhaps, the key phase in relation to the management of BMW. Effectively, there are two options: the BMW which is produced can either be managed on site (at or near the place of origin) or off site (away from the place of origin). On-site management relates mainly to either home composting or communal composting.

The manner in which waste is presented for collection for subsequent treatment off-site has a major influence on the options available for managing the waste stream. BMW can either be presented as part of the bagged waste fraction (i.e., mixed waste) or as separate fractions (e.g., paper and paperboard, food waste, garden waste and wood waste).

As mentioned in Section 3 and illustrated below in Table 9, there is considerable variation between countries in relation to the relative quantity of BMW that is separately collected, ranging from nearly 70 % in Flanders to 5 % in Catalonia. Countries that landfill less than 20 % of their BMW separately collect in excess of 40 % of BMW produced. It should be noted that this table presents data for the most recent year for which reliable information is available.

Table 9 **Landfilling, separate collection and bagged waste collection rates**

Country or Region	Year	% of BMW being consigned to landfill	% of BMW collected as Bagged Waste	% of BMW collected in separate fractions
Austria	1996	20.4	43.0	57.0
Denmark	1998	5.3	58.0	42.0
Ireland	1998	90.3	90.0	10.0
Belgium (Flanders)	1998	16.7	32.2	68.8
Finland	1997	64.9	70.0	29.3
France	1998	40.3	81.8	18.2
Germany	1993	N/A	N/A	23.5 [1)]
Germany (Baden-Württemberg)	1998	30.2	62.0	38.0
Greece		N/A	N/A	N/A
Iceland		N/A	N/A	N/A
Italy	1997	68.4	85.7	14.3
Luxembourg		N/A	N/A	N/A
Netherlands [2)]	1998	13.1	47.7	52.3
Norway	1997	59.0	68.7	31.3
Portugal		N/A	N/A	N/A
UK (England & Wales)	1998/99	86.2	72.1	27.9
Sweden		N/A	N/A	N/A
Spain		N/A	N/A	N/A
Spain (Catalonia)	1998	73.4	95.0	5.0

1) Refers to waste from households only.
2) Refers to waste from households only.
N/A: Information not available

There is, therefore, considerable evidence that widespread separate collection systems are an essential infrastructural requirement for large scale diversion of BMW away from landfill. Of course, the one exception to this would be the diversion of BMW collected as bagged waste away from landfill to incineration with energy recovery; however, such a simplistic solution would probably be in breach of Article 5 of the landfill directive which states that the strategy (to reduce biodegradable waste going to landfill) should include measures to achieve the targets by means of in particular, recycling, composting, biogas production or materials/ energy recovery.

The widespread use of separate collection systems is therefore the first step towards the development of a mix of diversion routes such as composting, recycling, biogas production and materials/energy recovery.

4.3.2. Collection of BMW in separate fractions

The main fractions of BMW which can be separately collected are paper and paperboard, food waste, garden waste, textiles and wood. Table 10 lists the different fractions of BMW which are separately collected, and/or delivered to civic waste facilities, by the various countries and regions examined.

Fractions of BMW collected separately Table 10

Country or region	Paper and paperboard	Food waste	Garden waste	Textiles	Wood
Austria	√	√	√	√	√
Denmark	√	√	√	X	X
Ireland	√	√ 1)	√ 3)	√	X
Catalonia	√	√	√	X	X
Baden-Württemberg	√	√	√	√	√
Belgium (Flanders)	√	√	√	√	√
Finland	√	√ 2)	√	√	√ 3)
France	√	√	√	√	√
Germany	√	√	√	√	√
Greece	√	X	√ 4)	X	X
Iceland	N/A	N/A	N/A	N/A	N/A
Italy	√	√	√	√	X
Luxembourg	N/A	N/A	N/A	N/A	N/A
Netherlands	√	√	√	√	X
Norway 5)	√	√	√	√	√
Portugal	√	√ 6)	√ 7)	√ 9)	X
United Kingdom (England & Wales) 8)	√	√	√	√	X
Sweden	√	√ 9)	√ 9)	X	X
Spain	N/A	N/A	N/A	N/A	N/A

1) Pilot scale at present.
2) With varying degree, such biodegradable waste fractions as food and garden waste are composted on-site, and therefore they are not collected separately.
3) Some of the wood waste is used on-site for energy recovery or recycling.
4) Collection has started. At present it is carried out in the area of the existing composting plant.
5) The collection system varies within the country. Regions which have a connection to an incineration plant, most likely do not collect all these fractions separately.
6) To commence in Lisbon in 2001.
7) Is only carried out in some municipalities.
8) Not all local authorities operate separate collection.
9) Is only carried out in some municipalities.

(Key √ — in use; X — not in use; N/A — no information available)

4.3.3. How are these fractions separately collected?

In general, there are three methods used to separately collect biodegradable municipal waste:

- direct from households (kerbside collection);
- use of collection receptacles in close proximity to households (bring banks); and
- delivery direct to civic waste facilities (recycling centres).

Direct from households

In general, there are four different collection receptacles used for the collection of the biodegradable fraction of municipal waste from households; biobins, paper bags, plastic bags (some of these may be biodegradable) and to a limited extent biodegradable bags. Biobins are generally made from plastic and are usually stored along with the collection receptacle used for storing the mixed waste fraction. The size of these bins range in general from 40 litres to 120 litres. Paper bags are often used for the storage of biodegradable municipal waste because the paper bag does not have to be removed prior to composting, as it will degrade during the composting process. This is usually facilitated by passing the bags through a shredder prior to the composting process. In some countries plastic bags of different colours are used for the collection of the different fractions of waste with the bags then being sorted optically in central plants. The disadvantage of the use of plastic bags for the collection of BMW is that the bag has to be removed prior to the composting process. The use of biodegradable bags for the collection of BMW is gaining popularity as, like with paper bags, they can be placed directly into the composting process. An additional advantage is that they are more durable than paper bags, which tend to disintegrate when they get wet. However, biodegradable bags tend to be more expensive than plastic or paper bags.

The frequency of collection varies between municipalities but is generally weekly or alternative weeks. During the summer, the food and garden waste fraction may need to be collected at greater frequencies in order to prevent nuisances such as, for example, odours etc. from occurring.

A key advantage of collection direct from households is that high participation rates are generally achieved.

Use of collection receptacles in close proximity to households
These usually consist of large containers which are located in close proximity to households in strategically located positions such as beside supermarkets, where householders can bring their separated waste fractions for collection. There is usually a colour-coded container designated to each waste fraction. Paper and paperboard, food waste, garden waste and textiles can all be collected in this way ([5]). In relation to food waste, householders are usually provided with either plastic or paper bags in which they place their food waste, which they then deliver to these collection points. The frequency at which these containers are emptied varies between municipalities and depends upon the fraction of waste that they contain, for example, greater frequencies for food waste. In some countries and regions, e.g. Catalonia, the food waste containers are emptied either on a daily basis or every second day. This frequency may be increased during the summer months to minimise potential nuisances. The receptacles are cleaned at least once in every two week period. This type of collection method is particularly suitable for areas with high residential densities with limited space available for larger containers.

Delivery direct to civic waste facilities (recycling centres)
A civic waste facility, also known as a recycling centre, is a facility at which waste may be directly deposited. In addition to accepting wastes like bottles, cans, batteries and electrical goods, these facilities may also accept paper and paperboard, food and garden waste, textiles and bulky household waste. These facilities are generally more suited for the collection of biodegradable municipal waste from less populated areas, e.g. rural locations, where it may not be economical to collect these fractions directly from the households.

4.3.4. Strategies and instruments in place to encourage source separation and separate collection

A number of different measures can be employed to encourage and increase the rate of separate collection. The following include the main measures that are usually employed:

- legal obligations requiring separate collection;
- the use of presentation by-laws;
- fiscal instruments; and
- sustained public education campaigns.

A combination of these measures is likely to be required if high separate collection rates are to be achieved.

Legal obligations requiring separate collection
A number of countries have introduced legal requirements for the separate collection of the biodegradable fraction of municipal waste. Depending on the country concerned, this obligation may extend to certain specific fractions like food waste and paper and paperboard. For example, in Austria, since 1995, there has been a legal obligation on municipalities to separately collect and treat organic waste from households. Similarly in Catalonia, since July 1999 municipalities with more than 5 000 inhabitants must carry out separate collection of the organic fraction of municipal solid waste. In Denmark, municipalities are legally obliged to collect 40–55 % of newspapers and magazines for recycling. The Danish municipalities are

(5) Some countries do not allow the collection of food waste in this way for public health reasons. Clearly, hygiene and public health concerns must rank highly when planning this type of collection activity.

also required to establish collection systems for food waste from canteens and restaurants that generate more than 100 kg of food waste per week. Since January 1994, all municipalities in the Netherlands have been required to separately collect food and garden waste from households. Dutch municipalities are also required to collect paper and paperboard and textiles separately.

Generally, these obligations are placed on municipalities by central government, with municipalities responsible for implementation. As with all such obligations, their relative success depends to a large extent on sufficient funding as well as the cultural conditions that prevail in a particular country in relation to how different levels of government cooperate with one another.

The use of presentation by-laws
An additional measure which is complementary to the one specified above is the use of by-laws or other legislative means which require householders or other waste producers, such as commercial enterprises and state institutions, to separate specific fractions of their waste and to present them for collection in the manner specified. This usually relates to the type of collection container to be used and the frequencies and dates at which these containers should be put out for collection. In Ireland, for instance, there is a provision under the Waste Management Act of 1996, the primary piece of national legislation in relation to waste, which provides municipalities with the power to pass by-laws specifically in relation to the manner in which waste is to be presented for collection.

Fiscal instruments
These generally include measures relating to the cost of collection and treatment of waste from households and other premises. The net effect of these instruments is to give the waste producer a financial incentive to either put out less waste for collection or to present waste in a manner which makes it more amenable to recovery. In a number of countries, the cost is based on the quantity or weight of waste put out for collection. Thus for those households that recycle a large proportion of their household waste, considerable reductions in costs can be achieved. In addition, where home and/or communal composting is carried out, similar cost savings can be achieved. In some cases, municipalities reduce their collection fees for those households where home composting is carried out e.g., Austria, some municipalities in Denmark, Sweden and Italy. In Flanders, collection costs are higher for unsorted wastes compared to sorted wastes.

Sustained public education campaigns
Public education campaigns are a vital part of the implementation of waste management strategies and plans. These campaigns are aimed at encouraging waste producers to, in the first instance, reduce the quantity of waste which they produce, and secondly to encourage source separation and recovery of waste.

Householders can be encouraged by informing them of the importance of their active participation in source separation schemes and the provision of advice. This can be achieved through the use of newsletters, visiting households and telephone helplines. It is essential that throughout these schemes householders are provided with positive feedback. Many schemes that had high levels of participation in the initial phase and where rates subsequently dropped, the fall-off in participation was primarily due to the lack of follow-up by the relevant municipalities.

4.3.5. Additional considerations
Prior to the commencement of any source separation scheme it is vital that markets and end uses for the products have been identified. This will help identify issues like relevant quality standards that are required to be achieved for certain products and thereby highlight considerations such as the level of contaminants that are acceptable/unacceptable.

4.3.6. Collection of BMW a bagged waste
BMW can also be collected as part of the bagged waste fraction. However, collecting BMW by this method restricts the routes by which it can subsequently be managed. Generally, mixed municipal waste is either landfilled or incinerated, although some countries have experience

in manual and mechanical separation of materials from the mixed waste stream. Due to the problems of contamination, source separation must be considered to be a better management option than attempting to separate out materials from the mixed waste stream.

4.4. Phase 3 — treatment

As illustrated in Figure 5, the treatment options available to treat BMW depend to a large extent on the way in which the waste is collected. The main options available are summarised in Table 11. The most widely used option for diverting bagged waste away from landfill is incineration. Other options include manual or mechanical sorting of the mixed waste stream to recover materials or reduce the organic content, or central composting for mass reduction only. Generally, attempting to recover materials from the mixed waste stream has not met with success due to contamination problems.

Table 11 **Options available for diverting BMW away from landfill**

Waste stream	Incineration	Gasification	Pyrolysis	Central composting for mass reduction	Composting	Anaerobic digestion	Recycling	Re-use	Manual or mechanical sorting
Wet mixed (bagged waste)	√			√		√			√
Refuse Derived Fuel (RDF)	√	√	√						
Food and garden					√	√			
Food					√	√		√	
Garden					√	√			
Paper	√	√	√		√	√	√		
Textiles	√	√	√				√	√	
Wood	√	√	√				√	√	

The options are considerably broader for separately collected fractions, ranging from relatively simple composting technologies to relatively complex thermal treatment options such as gasification and pyrolysis.

A key issue to address when deciding on the optimum approach to managing BMW and its component waste streams is the availability of markets and outlets for materials recovered from the waste stream. Prior to investing resources in the construction of facilities for recovery of BMW such as composting plants, anaerobic digestion plants or gasification plants, it is vital that end markets and outlets for the products produced have been identified. Market analysis will also help highlight issues such as relevant quality standards that are required to be achieved for certain products.

Key instruments to encourage the diversion of BMW away from landfill include the introduction of bans and restrictions on the landfilling of BMW or specific fractions of BMW, and the use of waste taxes, in particular landfill taxes and taxes that provide a financial incentive to divert waste away from landfill and/or incineration. Practical examples of the use and application of these instruments are presented in the case studies (see Sub-Section 4.6).

4.5. Phase 4 — final destination, end uses and markets

The final link in the chain is the final destination or end-use of the material, which will, to a large extent, be determined by the way in which the material is collected. Bagged waste will, in most cases, either be landfilled or incinerated, with or without energy recovery. Allowing BMW to be collected as bagged waste limits the options available for it further down the waste chain. However, even in countries with very high separate collection rates, there remains a significant quantity of waste that is, and in all likelihood will, continue to be collected as bagged waste, and management options are required to deal with this. Each country will have to decide, based on its own criteria, what it considers to be the best environmental, economic and political solution to managing this part of the waste stream. Ideally, national strategies should be geared towards reducing the quantities of BMW collected as part of the bagged waste stream, so that it can maximise the potential for recovery of the materials contained within the stream.

Wastes that are separated at source and collected separately have the potential to be recovered and put to beneficial use. However, if inadequate attention is paid to the quality of the recovered materials and to the development and maintenance of reliable markets and outlets for materials recovered from BMW, countries risk the creation of a separate waste management problem. It is therefore vital to address the question of markets and outlets for materials recovered from the BMW waste stream, and to ensure that structures are put in place that guarantee the reliability of these markets and outlets.

4.6. Case studies

A number of case studies are presented below from Denmark, the Netherlands and Flanders. These countries/regions have been chosen for the following reasons:

- less than 20 % of BMW produced is consigned to landfill;
- all employ widespread separate collection;
- all employ a mix of treatment options but with different profiles:
  - Denmark has the lowest reported landfill rate in Europe and has achieved high diversion rates by maximising energy recovery through incineration while also encouraging separate collection and recovery of specific materials, in particular, paper and garden waste;
  - the Netherlands has achieved high landfill diversion rates with a significant decrease in quantities of BMW landfilled between 1995 (28 %) and 1998 (13 %) mainly through an increased reliance on incineration (26 % in 1995 to 37 % in 1998). The Netherlands also has widespread separate collection and recovery of specific materials, in particular, paper, food and garden waste;
  - the Flemish region of Belgium has seen a significant drop in landfilling of BMW between 1995 (38 %) and 1998 (17 %). However, this has coincided with a decrease in incineration (31 % in 1995 to 22 % in 1998) and an increase in composting (16 % to 34 %) and recycling, mainly of paper (12 % to 23 %).

4.6.1. Denmark

Denmark has a low reliance on landfill and employs a range of treatment options for the management of BMW. In 1998, 5.3 % of BMW was consigned to landfill, 54.3 % to incineration with energy recovery, 29.6 % to composting, 10.4 % to recycling and 0.4 % to anaerobic digestion. The main diversion routes away from landfill are, therefore, incineration with energy recovery, mainly of bagged waste, and composting, mainly of garden waste.

Key strategies and instruments used in Denmark include:

- National policy in relation to the incineration with energy recovery of municipal wastes;
- a waste tax on both landfill and incineration to encourage recycling and recovery;
- a ban on the landfilling of wastes that are suitable for incineration;
- a legal requirement for the collection of newspapers and magazines for recycling; and
- a national policy on increased recycling of BMW.

Waste policy in Denmark is driven by the Danish Waste Model. Its fundamental principle is that coordination of waste management is a public sector task. To support this model, a broad range of instruments are applied. In relation to future planning, the Danish Government's waste management plan 'Waste 21' which addresses the period from 1998 to 2004, includes a description of the Danish strategy on biodegradable waste management. The strategy has two principal aims:

- to promote the separate collection of food waste from households and its treatment in anaerobic digestion plants (i.e. biogas plants); and
- to cease the landfilling of biodegradable waste and waste suitable for incineration (6). This waste must either be recycled or incinerated.

These measures will now be described in more detail.

Phase 1 — production
Home composting
In 1998, 179 000 households were served by municipal home composting schemes, with approximately 152 000 households actively participating. A municipal home composting scheme entails the municipality providing containers to households for the purpose of home composting. The containers are either provided free or for a minimal cost. Where home composting is being carried out, a corresponding decrease in the quantity of bagged waste is expected. Where this occurs, a number of the municipalities charge a lower collection fee for household waste. Between 22 200 and 23 700 tonnes of food waste is treated annually by this method. Both the number of households participating in and the number of municipalities running home composting schemes have increased considerably since 1993. In 1993, approximately 58 000 households and 51 municipalities participated in home composting schemes. By 1997, 152 000 households in 86 municipalities were participating in such schemes.

Phase 2 — presentation, collection, transfer and movement
Separate collection
Relatively high separate collection rates exist in Denmark. It is therefore of interest to identify the reasons behind this.

Paper
Since 1990 all municipalities have set up recycling schemes for paper and paperboard generated by the household sector. Today, 39 % of paper from households is collected for recycling.

The statutory order on waste, No 619 of 27 June 2000 stipulates that at least 40 % of each local authority area's household paper and cardboard potential must be collected in 2001. From 2002 and onwards a minimum of 55 % must be collected and recycled. If a local authority is unable to meet these collection targets, or if it does not want to document that it meets them, it must establish kerbside collection schemes with fixed equipment for paper and establish collection schemes for cardboard in areas inhabited by more than 1 000 people. Kerbside collection will entail additional costs of approximately EUR 8.05–13.42 per household, depending on the types of housing and the system chosen.

In general, approximately 50 % of households (information on the breakdown between single and multi-family dwellings are unavailable) are served by a separate collection scheme for paper and paperboard with the remaining 50 % having access to separate collection receptacles at civic waste facilities (recycling centres).

Single-dwelling households are served by either separate collection direct from the house or through delivery of the separated waste to civic waste facilities. In general, for multi-family dwellings, the collection system available consists of separate collection receptacles in close proximity to the dwellings.

In relation to commercial activities, many municipalities require that companies which produce more than for example 50 kg of paper or 50 kg of paperboard a month, are obliged to sort it out for recycling and are obliged to arrange for its collection from their own premises.

(6) The term 'waste suitable for incineration' includes waste with positive heating value e.g., bagged waste, but not waste which according to the Danish waste legislation, is prohibited to incinerate (e.g., PVC), waste which results in environmental problems during incineration and waste as, according to the national or local legislation, that must be separated for recycling or special treatment.

The collection of paper from households will be increased by using more efficient collection systems and collecting more types of paper. In addition, barriers to the recycling of paper, such as the use of glue, will be evaluated (Danish Ministry of Environment and Energy, 1999).

Garden waste
The majority of municipalities have in operation schemes for the separate collection for garden waste even though there is no legal requirement for such waste to be separately collected. Presently, 50 % of households are served by a separate collection scheme for garden waste with the remaining 50 % having access to separate collection receptacles at civic waste facilities (recycling centres). The collection and delivery systems for garden waste for single and multi-dwelling families are similar to those described for paper and paperboard above.

The objective for 2004 is 95 % recycling of garden waste. Anyhow, the amount of separately collected garden waste continues to increase and the former estimates of total amounts are too low. The present efforts will be maintained and no new initiatives are envisaged (Danish Ministry of Environment and Energy, 1999).

Food waste
Municipalities are not obliged to establish separate collection schemes for food waste from the household sector. However, approximately 20 % of the municipalities have set up such schemes which serve about 13 % of the total number of households. Many of these municipalities have chosen to establish home composting schemes instead of separate collection schemes. Food waste is not accepted at civic waste facilities.

The Danish municipalities are required to establish collection systems for food waste from canteens and restaurants that generate greater than 100 kg of food waste per week (7). They are also required to collect the biodegradable fraction arising from supermarkets. This does not form part of the municipal waste.

A collection scheme for the organic fraction arising from supermarkets, bakeries, greengrocer's shops, lunchrooms/canteens in enterprises, national schools, retirement homes etc., is presently being examined (European Commission Environment DG, 1997).

At present 13 % of households are served by separate collection schemes for food waste. The Danish Government aim to increase the quantity of food waste separately collected from private households for subsequent treatment by anaerobic digestion. However, at present the technology is not sufficiently developed to establish a compulsory collection scheme in all municipalities. To promote the development of anaerobic digestion technology the government is providing economic support for the establishment of new plants. Thus the capacity for treatment of food waste from households in anaerobic digestion plants is expected to rise from 20 000 tonnes in 2000 to 70 000–100 000 tonnes in 2004. *Waste 21* specifies a target of 100 000 tonnes of BMW to be treated by anaerobic digestion.

The government's target is to increase the collection and treatment of food waste from households from 51 000 tonnes (1998) to 150 000 tonnes for composting and anaerobic digestion in 2004. Co-treatment of food waste and farm slurry at joint anaerobic digestion plants has first priority for the Danish Government.

Biodegradable waste from canteens and restaurants are presently reprocessed into animal feeds. *Waste 21* recommends that an evaluation be carried out to clarify whether other forms of recycling may be of relevance. Rules for the schemes will therefore be studied and adjusted as necessary.

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(7) Statutory Order No 883 of 11 December 1986 on municipal collection of food waste from catering centres.

Phase 3 — treatment

Incineration with energy recovery

Incineration with energy recovery is the primary treatment route for BMW in Denmark, with 54.3 % of this waste stream incinerated in 1998. Incineration is mainly employed for the treatment of bagged waste.

One of the objectives of the Danish waste management plan is to adjust the capacity of incinerators to actual needs and to locate them in areas where the best possible energy utilisation and largest possible CO_2 mitigation are obtained, taking into consideration principles of regional sufficiency. In recent years, most plants in Denmark have been upgraded for combined heat and power generation, as a number of the incinerators generated heat only. The future aim is to have all incinerators equipped for combined heat and power generation.

Waste taxes

In 1987 Denmark introduced a tax of EUR 5.37/tonne on waste going to landfill and incineration. This was to encourage a shift from landfilling and incineration to recycling. Today, the tax is almost 10 times higher and is differentiated between waste going to landfill (EUR 50.55/tonne) and waste for incineration (EUR 37.58 with combined power and heat generation and EUR 45 with only heat generation). There is no tax on waste for recycling, composting and anaerobic digestion.

The percentage of waste going to landfills has decreased from 39 % in 1985 to 16 % in 1997. The target for 2004 is 12 % to landfill. The largest share of this decrease can be attributed to the recycling of construction and demolition waste (Danish Ministry of Environment and Energy, 1999).

Ban on the landfilling of biodegradable waste

In 1997 the Danish Government introduced a ban on the landfilling of waste suitable for incineration. Thus biodegradable waste which is not treated biologically or otherwise recycled must be incinerated. This regulation has proven to be very successful, having resulted in the diversion of significant quantities of waste away from landfill.

However, at present there is insufficient incineration capacity in Denmark to cope with the expected increase in amounts of waste. As a practical measure to deal with this, when insufficient incinerator capacity exists, biodegradable waste fractions, which degrade the slowest, e.g., wood and plastic, are temporarily packed in plastic bales or placed in designated cells in landfills. When incinerator capacity becomes available, the biodegradable fraction, which was landfilled, has to be dug out and transported to an incinerator for treatment. Incineration capacity is presently being enlarged and is expected to be sufficient in a few years. Bagged or mixed waste is the first priority for incineration. The government's future aim is to shift from incineration to increased recycling and at the same time to shift non-combustible waste directly from landfilling to recycling (Danish Ministry of Environment and Energy, 1999).

Phase 4 — end use/final destination

Compost quality and use

The general guidelines for use of compost and anaerobic digestate for farming purposes are specified in the Ministry of the Environment and Energy Statutory Order No 49 of 2000. Most compost produced complies with the required standards. The authority generally supervising the quality of compost is the Ministry of Agriculture and Fishery with the 'Plantedirektoratet' controlling the quality of compost by carrying out spot checks.

There are a number of different end-uses for compost in Denmark. Approximately 50 % of the composting plants in Denmark are selling the compost for approx. EUR 8.70/tonne (DKK 65 in 1999). The remainder either give the compost away free of charge or they utilise it within their municipalities. Compost made from pure garden waste often obtains higher prices than compost made from food waste or sewage sludge.

4.6.2. The Netherlands

Although the quantity of household waste increased by 13.4 % between 1995 and 1998 in the Netherlands, the quantities of biodegradable municipal waste being consigned to landfill decreased by more than 50 % over this three-year period. The Netherlands has, for many years, had a low reliance on landfill and employs a range of treatment options for the management of BMW. In 1998, the year for which the most recent data is available, 13.1 % of biodegradable waste from households was consigned to landfill, 36.5 % was consigned to incineration with energy recovery, 33.3 % consigned to composting and 19 % to recycling.

Key strategies and instruments used in the Netherlands include:

- waste prevention and minimisation
- producer responsibility
- high level of separate collection
- ban on the landfilling of biodegradable wastes
- standards for compost quality and use
- landfill and incineration taxes
- other fiscal measures.

Phase 1 — production

Waste prevention

A number of instruments are used in the Netherlands to promote waste prevention, ranging from voluntary to regulatory instruments. Various agreements on prevention have been reached with industry, e.g. an agreement has been reached with the packaging industry to reduce the quantity of packaging brought onto the market (Ministry of Housing, Spatial Planning and the Environment, 1998).

The provision of information is also an important prevention instrument which is used. Publicity campaigns such as ‘Less waste is up to you’ have been undertaken to encourage the general public to do more to prevent waste from arising in the first instance.

The Association of Dutch Municipalities and the Association of Provinces together with the Ministry of Housing, Spatial Planning and the Environment have prepared a Prevention Implementation Strategy which covers the period 1996–2000. The Strategy aims at encouraging companies to prevent waste arising and focuses on all companies and all types of waste thus including those sectors for which no separate policy had previously been devised. This strategy is implemented through the use of both voluntary and regulatory instruments. Where possible, these are integrated into existing instruments, i.e. permits and target group consultations with industry (Ministry of Housing, Spatial Planning and the Environment, 1998).

Although it is very difficult to measure the effectiveness of waste prevention measures, there has been a stabilisation in the quantity of waste arising in the Netherlands over the last few years despite the growth in the economy, consumption and the number of households. It is considered that the waste prevention measures have contributed to this (Ministry of Housing, Spatial Planning and the Environment, 1998).

Producer responsibility initiatives

These are initiatives or obligations undertaken by those involved in the manufacture, distribution and sale of products. These can be effective tools for making producers take greater responsibility for their end-of-life goods. They can take the form of either voluntary or statutory requirements or a combination of both, e.g. the paper and paperboard industry have reached agreement with the local authorities that all paper and paperboard which is separately collected from households can be handed over at least free of charge. This provides security to local authorities by providing a viable and secure outlet for their collected waste which in turn encourages local authorities to increase the quantity of paper and paperboard which they separately collect. Local authorities have in response to this, committed themselves to collecting 85 % of the eligible paper and paperboard from households.

In addition, the fraction of bulky household waste for which it is possible to attribute to an individual producer, approximately 80 % are covered by systems of producer responsibility that are either presently in operation or are in preparation (Ministry of Housing, Spatial Planning and the Environment, 1998).

Phase 2 — presentation, collection, transfer and movement
Under the Environmental Management Act, 1994, local authorities are required to set up separate collection systems for biodegradable waste from households. Three fractions are separately collected; paper and paperboard, food waste and garden waste.

Paper and paperboard
In April 1995, the Waste Management Council published a programme on 'Separate collection of household waste'. The programme recommended that the most suitable method for collection of paper and paperboard was mono-collection (i.e. collection solely for this fraction) by means of a door-to-door collection service with a frequency of at least once every four weeks. It was estimated that this would result in a collection response of 85 % by the year 2000.

Local authorities are required to collect paper and paperboard separately from households. Also under the terms of the packaging covenant II, the government and industry have agreed that local authorities will be responsible for the collection of paper and paperboard and for financing such collection. However, transportation from the subsequent collection point (e.g., local authority depot) and further treatment will be arranged and financed by the paper and paperboard industry. In the case where the collected material has a market value, the local authorities will be compensated, however, if the collected material has a negative market value, the local authorities will be able to transfer the collected material free of charge. This fraction of paper and paperboard referred to under the packaging covenant also includes non-packaging paper and paperboard.

In 1996, 47 % of the total quantity of paper and paperboard from households was separately collected for recycling. The recycling target for the year 2000 is 85 % (Ministry of Housing, Spatial Planning and the Environment, 1998).

Food and garden waste
The term 'organic waste' is used in the Netherlands to describe the food and garden waste fraction of BMW. This garden waste fraction does not include thick branches. The separate collection of 'organic waste' was introduced in 1992/1993.

As stated above, under the Environmental Management Act, 1994, local authorities are required to collect the biodegradable fraction of household waste separately. However, source separation and separate collection is not compulsory when it is not suitable for technical or economic reasons e.g., for households in old high-rise buildings in city centres (European Commission Environment DG, 1997). Organic waste is collected separately in all municipalities in the Netherlands with approximately 75 % of the population participating in the schemes (Ministry of Housing, Spatial Planning and the Environment, 1998). Local municipal regulations require households to separate both waste streams (European Commission Environment DG, 1997).

Home composting does not form part of the national strategy.

Phase 3 — treatment
Ban on the landfilling of organic wastes
In conformity with the order of preference for waste disposal, the waste (landfill ban) decree came into force in 1995. This decree prohibits the landfilling of waste which can be reused/ recycled or incinerated with energy recovery. The decree bans the landfilling of 32 categories of waste coming from both households and companies, with the timing at which the decree comes into force differing per category. Since 1995 the ban has included household waste, paper and paperboard, organic household waste and packaging. Since 1997, the ban has been extended to wood waste. The decree enables the provincial authorities to grant exemption from the landfill ban to operators of landfills, for example, if there is a temporary

shortage of incineration capacity. However, the provincial authority is only allowed to do so if it has obtained a statement from the Environment Minister indicating that at that time in the Netherlands no other processing option other than landfill is available for that particular waste (Ministry of Housing, Spatial Planning and the Environment, 1998).

Importation of combustible waste is permitted into the Netherlands as long as this does not jeopardise the incineration of Dutch waste. Importation of waste for landfill is not permitted (Ministry of Housing, Spatial Planning and the Environment, 1998).

Landfill and incineration taxes
Costs of incineration have been high for the last number of years due to the advanced technology including extensive flue-gas cleaning that is required. Landfill prices have gradually increased through the imposition of a tax. Taxes on the landfilling of reusable or combustible waste are now as high as the highest incineration prices. Exemptions from this tax can only be obtained if there is insufficient incineration capacity available, as discussed above.

These increased costs have had a positive effect on prevention and reuse/recycling. Reuse/recycling has risen dramatically in the past number of years. In 1985 approximately 49 % of total waste arisings were reused/recycled. By 1996 this figure was approximately 73 % (Ministry of Housing, Spatial Planning and the Environment, 1998).

Other fiscal measures
The collection and disposal of the organic fraction of municipal waste is financed through municipal charges on waste put out for collection. Various mechanisms are employed including a tax on refuse bags or taxes based on the size of the household, the size of the container, the frequency of emptying the container or the weight of waste collected per household. Overall, these taxes are resulting in a higher level of source separation of materials for reuse and recovery. However one of the side effects can be the illegal disposal of waste (European Commission Environment DG, 1997).

Phase 4 — end use/final destination
Compost quality and use
The decree governing the quality and use of other organic fertilisers (BOOM) which is part of the fertiliser law, sets standards for the use of compost in addition to sewage sludge and top soil. Compost made from the biodegradable fraction of household waste meets these standards and may be used in specified amounts. In addition to these statutory standards, the industry producing compost from the biodegradable fraction of household waste has drawn up a certificate of its own (Ministry of Housing, Spatial Planning and the Environment, 1998). This certificate covers both process control and final product matters. Over the past number of years the demand for compost made from biodegradable household waste has grown to such an extent that in 1997 demand exceeded supply. This is mainly due to promotional campaigns and other similar activities (Federal Ministry for Environment, Youth and Family Affairs, 1998).

4.6.3. Belgium — Flanders
There is a relatively low reliance on landfill in Flanders where various other management options are utilised. In 1998, BMW was managed in the following manner: 16.7 % landfill; 22.1 % incineration with energy recovery; 34.3 % composting; 22.8 % recycling; 4.1 % reuse. Recent trends indicate a significant increase in the quantity of food and garden waste recovered and a significant decrease in the quantities of BMW incinerated, which makes Flanders an interesting case study.

Key strategies and instruments used in Flanders include:

- ban on landfill of certain separately collected waste streams
- ban on incineration of certain separately collected waste streams
- separate collection schemes
- increasing levels of composting

OVAM, the Flemish Public Waste Office, was established in 1981 as a result of the Waste Decree of the Flemish Government. This Decree is based on the waste hierarchy, with prevention the most desirable option. Since biodegradable waste accounts for about half the total municipal waste produced in Flanders, the policy with respect to the organic fraction is therefore very important in achieving the overall desired result of the waste policy.

The existing policy in relation to this is laid down in the 'Masterplan VFG waste and green-areas maintenance waste'. VFG waste (vegetable, food and garden waste) includes easily degradable fine garden waste materials. Other garden waste from households, along with garden waste from maintenance of public areas, is referred to as 'green waste'. VFG consists of 28 % kitchen waste, 71 % garden waste and 1 % contaminants (some plastics) (European Commission Environment DG, 1997).

The following priorities appear in the Masterplan:

- promotion of prevention (home composting, direct reuse of chips after shredding of garden waste)
- maximisation of the separate collection and treatment of garden waste (called 'green waste' in Flanders)
- maximisation of the separate collection and treatment of VFG waste

Phase 1 — production

Flanders proposes to introduce the 'Diftar' system for the collection of municipal waste. This is operated according to the polluter pays principle. Each waste receptacle will contain an electronic chip, which will contain data in relation to the owner of the waste receptacle. Upon collection the waste receptacle is weighed and the waste produced is quantified in this manner. This system provides an incentive for householders to carry out home composting and to separate other suitable waste at source, prior to collection. As already stated, waste collection charges are higher for collection of mixed waste than for separated waste.

It is also planned to provide demonstration places for home composting. An education programme is planned to encourage people to carry out home composting. In addition to this, there will be an evaluation of existing systems with the aim of improving the quality of separately collected waste.

Phase 2 — presentation, collection, transfer & movement

Separate collection

Flanders achieves a high rate of separately collected BMW. In 1998, 68.8 % of total BMW was separately collected. More than half of this was accounted for by separately collected food and garden waste. Participation in separate collection of food waste is 57 % and for garden waste is 96 %. Cost for collecting unsorted household waste is greater than cost for separate collection so there is an incentive to separate suitable wastes at source.

Food Waste (called 'Biowaste' in Flanders)

The Biowaste and Vegetational Waste Execution Plan was published in 1995. In 1997, approximately 2.7 million people were served by separate collection of food waste (i.e. VFG waste as previously described). This refers to the biodegradable fraction of household waste and is collected in different size receptacles, usually every two weeks. Receptacles may be biobins or biodegradable plastic bags. In 1998, separately collected food and garden waste accounted for 37.5 % of total BMW produced and 56.1 % of the total quantity of BMW separately collected.

Garden waste (called 'vegetational' waste in Flanders)

The execution plan stated that by the end of 1997, each inhabitant of Flanders would have access to separate collection of garden waste. By the end of 1997, separate collection of garden waste (biodegradable waste generated by gardening and maintenance activities in public and private gardens and parks) was available to about 5.8 million people. The quantity of this waste arising from professional gardeners in 1997 was estimated to be less than 10 000 tonnes. Garden waste is either collected by the kerbside method, usually presented in bulk, or by means of the bring method. However, some regions also offer biodegradable plastic or paper bags for the collection of garden waste, with or without an additional charge. In such cases, the collection frequency is generally higher than for collection in bulk. In some cases, there is door-to door shredding of garden waste so that the producer can re-use the chips.

Paper and paperboard
The next greatest quantity of separately collected BMW is paper and paperboard, accounting for 30 % of the total amount of separately collected BMW and 20.1 % of the total quantity of BMW produced. Separate collection of this waste stream was introduced between 1991 and 1995. This is achieved through door-to-door collection at least once every month, and a cardboard box receptacle is used. Paper and paperboard may also be delivered to container parks. In 1998, there was 100 % participation in separate collection of paper and paperboard in Flanders.

Others
Separate collection services are also provided for textiles and wood. Textiles account for 1 % of total BMW produced and 1.4 % of the total quantity of BMW separately collected. Wood accounts for 3 % of total BMW and 4.5 % of the total amount of separately collected BMW.

Phase 3 — treatment
Increased levels of composting
There was a significant increase in the quantity of BMW composted from 16.3 % in 1995 to 34.3 % in 1998. Garden and park waste is composted centrally in the open air while VFG waste is mainly composted at central in-vessel composting plants. Home composting reduces collection costs for households. Composting bins for home composting are subsidised by the government. The aim is to have qualified composting experts in as many municipalities as possible, in order to provide support to those households where home composting is being carried out.

Incineration bans
There is a ban on the incineration of certain biodegradable wastes in Flanders. Since 1 July 1998, the incineration of separately collected food and garden waste and separately collected paper and paperboard waste has been banned. Since 1 July 2000, this ban has extended also to non-sorted municipal waste. However, in 1998, incineration with energy recovery still accounted for 22.1 % of the total quantity of BMW produced in Flanders. The majority of this quantity was accounted for by biodegradable municipal waste collected as bagged waste. There is a distinct shift away from incineration of BMW in Flanders, decreasing from 31.2 % of total BMW produced in 1995 to 22.1 % of total BMW in 1998.

Waste taxes
In 1998, the following taxes applied to incineration of municipal waste in Flanders: EUR 6/ tonne if energy recovery takes place and 13 EURO/tonne if there is no energy recovery. In relation to landfilling of municipal waste in 1998, a tax of EUR 55/tonne normally applied. However, if energy regeneration takes place as a result of the collection and utilisation of landfill gases, the tax on landfilling is reduced to EUR 52/tonne. As can be seen, tax on waste going to landfill remains significantly higher that the tax on waste going to incineration. As a result of these waste taxes, there was a considerable reduction in the quantity of BMW landfilled and incinerated between 1995 and 1998.

Ban on the landfilling of biodegradable waste
There is a policy of banning the landfilling of certain biodegradable wastes. Since 1 July 1998 separately collected paper and paperboard waste, separately collected food and garden waste and municipal waste from households has been banned from all landfills in Flanders. The quantity of BMW being landfilled decreased from 37.3 % of the total quantity of BMW produced in 1995 to 16.7 % in 1998.

Phase 4 — end use/final destination
Compost quality and use
The trading in fertilisers and soil improving agents is regulated by the Royal Decree (Koninklijk Besluit) of 1977 which was amended in 1986 and again in 1990. Compost made from VFG waste and garden waste is not specified by this legislation. However, the 'Inspection

of raw materials' branch of the Ministry of Agriculture is able to issue temporary permits to use fertilising and soil improving agents which are not defined in this Royal Decree. Such permits have been granted for compost made from VFG waste and from garden waste once it complies with specified standards (European Commission Environment DG, 1997).

In 1992 the Public Waste Company for Flanders (OVAM) set up the Flemish organisation VLACO for promotion of the above type of compost. VLACO is a cooperation between OVAM, communities, private compost producers, some cities and compost distributors and producers of growing media/soil conditioning products. The major tasks of VLACO are compost marketing, compost quality control and research (Federal Ministry for Environment, Youth and Family Affairs, 1998). Compost which meets the quality standards of VLACO, which are stricter compared to those of the Ministry of Agriculture and which is produced in accordance with an integrated process control can get the VLACO quality label. This quality system was set up by VLACO to promote the sale and application of this type of compost. The quality standards of VLACO are in accordance with the Dutch standards for this type of compost which is regulated in the decree on other organic fertilisers (BOOM) and the German standards as specified by the Federal Compost Association (Bundesgutegemeinschaft Kompost). In addition, the quality parameters are required to be analysed by the standard methods specified by the Ministry of Agriculture both during and after the composting process (European Commission Environment DG, 1997).

There are numerous end-markets for compost produced in Flanders. In 1997, 30 % was sold for use in landscaping, 18 % for private use, 15 % as potting soil, 11 % to soil mixing companies, 8 % to other wholesalers, 6 % to horticulture, 5 % for agriculture, 3 % for soil sanitation and the remaining 4 % was exported mainly to the north of France where it was used in vineyards (European Commission Environment DG, 1997).

4.7. Conclusions

It is clear for the three case studies presented that a suite of strategies and instruments were successfully used to achieve the twin objectives of better BMW management, i.e.

1. High rates of diversion of BMW away from landfill

2. High rates of recovery, in particular, material recovery, of BMW diverted away from landfill.

Countries that have made significant strides towards achieving these objectives have certain things in common. In particular, there is significant state intervention in all cases to encourage, on the one hand, high levels of separate collection and, on the other hand, high levels of diversion away from landfill, and in some cases, diversion away from incineration as well. This intervention mainly consists of legal requirements for separate collection of specific waste streams and taxes and restrictions on the landfilling and incineration of specific waste streams.

The net effect of encouraging separate collection and restricting disposal outlets is that:

- the quantity of material available for recovery is maximised, and
- the available routes for disposal of materials are curtailed.

This is clearly illustrated by the case studies presented above. In all three cases, the countries and regions involved have high levels of separate collection leading to relatively large quantities of waste destined for recovery. Recovery routes vary from one country to another with an interesting contrast to be seen between Denmark, with its high dependence on incineration with energy recovery and Flanders, where incineration of municipal waste is essentially being phased out. To a large extent, local conditions and markets will determine the most appropriate mix of options for a particular country and region. For instance, incineration of municipal waste is an important element of general energy policy in Denmark, where many district heating schemes are in existence, and thermal treatment is therefore likely to continue as a key component of the BMW management strategy.

The risks involved in pursuing a strategy of large-scale separate collection and tight restrictions on disposal are also worth considering. First of all, if adequate and reliable outlets are not available for the materials being separately collected, countries and regions investing heavily in separate collection risk the creation of a separate waste management problem. This means that the question of adequate and reliable outlets for compost and paper, in particular, needs to be fully addressed, preferably before large-scale separate collection systems are put in place. At the very least, integrated plans are required at both local and national level to ensure that there is linkage between collection of waste materials from households and business premises, the processing and quality of these materials and the subsequent use of end-products such as compost or recycled fibre.

The other risk attached to the strategy is an increase in illegal dumping of waste by waste producers and waste handlers looking for ways to avoid paying higher costs associated with such a strategy. However, the possibility of illegal activity should not be allowed to impair the implementation of measures to meet the targets set by the landfill directive. It could also be argued that one of the best defences against illegal dumping is the provision of an adequate network of facilities in advance of imposing legal restrictions on disposal. This means, for instance, that where countries are planning to introduce bans or restrictions on the landfilling or incineration of specific parts of the BMW waste stream, sufficient time should be allowed and resources invested to ensure that alternative arrangements are in place for the waste to be diverted away from disposal.

5. Key issues and proposed indicators

The key issues identified in relation to meeting the targets set out by the landfill directive are discussed below, along with conclusions where they arise. A set of indicators has also been developed which are presented below (Table 12).

5.1. Identification of key issues

Key issues identified at the start of this project were:

- available options for diversion of biodegradable waste away from landfill;
- available options for separate collection of biodegradable waste;
- appraisal of treatment options used to date, including composting, anaerobic digestion, and incineration;
- impact of diversion of biodegradable waste away from landfills;
- environmental consequences of choosing particular diversion options such as composting, anaerobic digestion and incineration;
- quality and market issues for products such as compost from biodegradable waste;
- standards for products produced from the recovered waste;
- fiscal instruments including landfill and other taxes; and
- definition of indicators for biodegradable waste suitable for national and EEA indicator-based reporting.

In preparing this project, some key issues of particular importance have been identified which require consideration when planning for compliance with the targets set by the landfill directive for diversion of BMW away from landfill. These are:

The need for good quality and consistent information
A standard approach to tracking progress towards the landfill directive targets is needed. A standard approach to tracking BMW flow in individual countries would also be a useful tool to measure progress towards the achievement of the targets.

However, based on the information supplied by EEA member countries during the course of this project, there are considerable gaps in information at national level. Many countries had difficulty describing the flow of BMW in their jurisdictions. Reliable waste flow information is an essential building block of any national strategy and ongoing efforts are therefore required to establish harmonised systems of data collection and reporting. It is rather alarming that the relatively simple formats for reporting summary information on BMW production and management provided such difficulty for so many countries, mainly due to an absence of basic information at national level.

A problem also exists in relation to the definition of biodegradable municipal waste that results from the well-documented difficulties that exist in relation to the definition of municipal waste. It is worth repeating the earlier conclusion, in relation to this matter, that the definition provided in the landfill directive was the most practical from the point of view of comparing one country to another since it is simply defines municipal waste as household-type waste from any source.

The operational definition provided in sub-section 2.1 of this report is recommended for the purpose of gathering data on biodegradable municipal waste, and it follows on from the approach to investigate the comparability of household and municipal waste. There is, however, **a requirement for more detailed descriptions of the actual waste types to be considered as well as guidelines on how to establish the composition of the bagged (mixed) waste component**.

Integrated approach to developing national strategies
The experience of countries and regions that have succeeded in diverting large quantities of BMW away from landfill strongly suggests that an integrated package of options is needed at national level to achieve high diversion rates. Countries with high rates of diversion of BMW away from landfill employ a combination of separate collection, thermal treatment, centralised composting and material recycling. Thermal treatment, mainly incineration, is generally used for the treatment of bagged waste while composting, re-use and recycling are employed for separately collected wastes such as paper and cardboard, garden wastes, textiles, wood and, to a lesser extent, food wastes. Technologies such as anaerobic digestion, gasification and pyrolysis are in use to a lesser extent, although as the technologies develop their use could become more widespread.

Therefore **countries should identify a range of options for managing BMW away from landfill. These options should be linked clearly to available markets and outlets for materials diverted away from landfill**. This will require the development of plans for the management of both the mixed waste stream and specific materials separated from the waste stream, in particular food waste, garden waste and paper/cardboard waste. Countries that currently collect the bulk of BMW as part of the mixed waste stream clearly need to plan for both radical reductions in the quantity of mixed waste collected and radical increases in the separate collection of specific materials.

Collection systems
All countries and regions surveyed employ a mix of traditional 'bagged waste' collection and separate collection. Generally, traditional 'bagged waste' is either landfilled or incinerated, although some non-thermal treatment also occurs, such as central composting for mass reduction only. The key to achieving both high landfill diversion rates and high re-use, recycling and composting rates (i.e. recovery other than energy recovery) appears to be the provision of widespread separate collection facilities, together with the availability of adequate capacity and markets for the materials thus collected.

Source separation and separate collection should therefore be considered for inclusion in national strategies for meeting the targets set by the landfill directive

This suggestion comes with a note of caution. Each country will need to work out a realistic and achievable target for source separation and separate collection so that it is reasonably confident that the quality of the recovered materials are sufficiently high and that viable markets and outlets exist.

Treatment options
At present, there appears to be a relatively small number of proven treatment options available for BMW diverted away from landfill. The three principal alternatives in use at present are **incineration with energy recovery**, mainly of bagged waste, **central composting**, mainly of garden wastes (and, to a lesser extent, food wastes) and **material recycling**, mainly for paper and cardboard wastes. Some other routes are in use such as anaerobic digestion and use of food waste as animal fodder, but generally, for relatively small quantities of waste. More recent or emerging technologies such as gasification and thermolysis may also play a role in national strategies for the management of BMW.

Availability of markets and other outlets for compost and other end products
As stated earlier in this report, if adequate and reliable outlets are not available for materials being separately collected, countries and regions investing heavily in separate collection risk the creation of a separate waste management problem. **National planners should be fully aware of the importance of establishing and maintaining adequate markets and outlets when drawing up national strategies and plans for the diversion of BMW away from landfill.**

Bans and restrictions on landfilling/disposal taxes
A key instrument available to individual countries is to impose bans or restrictions on the landfilling of specific waste streams or to tax disposal in order to make recovery a more economically viable option. Perhaps the optimum approach is **to have a combination of progressive restrictions on acceptance of specific waste streams at landfill together with a**

taxation system that increases the cost of landfilling to a point where it is no longer a financially attractive option. However, whatever approach a country chooses to take, it is essential that alternative routes be identified in advance for waste diverted away from landfill.

Monitoring national strategies for BMW
The landfill directive sets out clear targets and a clear timeframe for reducing the absolute quantity of BMW being consigned to landfill. By basing the target on 1995 production data, a clear roadmap is available for each country, provided that reliable data or, at least, agreed data, is available for BMW production in 1995, in accordance with the requirements of the Directive. This roadmap is illustrated for each country in the BMW management sheets, which can be downloaded from www.eea.eu.int. The net impact of future growth in BMW production, were this to happen, is that larger quantities of BMW will require treatment by routes other than landfill. It is therefore essential that, as part of its national strategy, **each country sets up a monitoring and management system that will allow it to track BMW production and management on a continuous basis**. Such a system would make the link between production of BMW, its subsequent management and the final destination or use of materials, such as compost, produced through its management. Monitoring should be conducted on a continuous basis so that instruments and strategies in use to divert BMW away from landfill are regularly audited and checked for their relative effectiveness and remedial action taken where necessary.

5.2. Proposed indicators

The following is a list of indicators that are considered useful in tracking progress towards the targets and objectives set by the landfill directive (priority indicators are highlighted in bold). An overview of these priority indicators is presented in Table 12 for countries where data was available.

Directive target
Quantity of BMW landfilled as a percentage of BMW produced in 1995

Production of BMW
Quantity of BMW produced per annum
The ratio of BMW to MW
Per capita production of BMW (tonnes/annum)

Collection of BMW
% of BMW separately collected
% of BMW collected as bagged waste

Treatment of BMW
% of BMW produced that is landfilled (each year)
% of BMW produced that is subjected to thermal treatment (each year)
- % of BMW incinerated with energy recovery
- % of BMW incinerated without energy recovery
- % of BMW subjected to other thermal treatments

% of BMW produced that is recovered by means other than incineration with energy recovery
- % of BMW composted
- % of BMW anaerobically digested
- % of BMW recycled
- % of BMW re-used

Use of products produced from BMW
% of compost produced that was put to beneficial use

Proposal of priority indicators for tracking BMW management Table 12

Country or region	Production indicator	Landfill directive target indicator [1]		Collection indicators		Treatment indicators [2]			
	BWM production/capita [4] (tonnes/person/annum)	1995	Latest year	% of BMW collected as bagged waste	% of BMW collected in separate fractions	% of BMW being consigned to landfill	% of BMW being consigned to Incineration	% of BMW being consigned to other recovery processes	Year [3]
Austria	0.19	20.2	21.5	43.0	57.0	20.4	13.3	58.5	1996
Denmark	0.35	11.3	5.8	58.0	42.0	5.3	54.3	40.5	1998
Belgium (Flanders)	0.28	37.3	3.9	32.2	68.8	16.7	22.1	57.1	1998
Finland	0.33 (1994)	65.2	64.9	70.0	29.3	64.9	5.8	28.6	1997
France	0.27	38.0	42.8	81.8	18.2	40.3	35.7	12.7	1998
Germany	0.35 (1993)	70.2 [5]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Baden-Württemberg	0.57	42.7	29.1	62.0	38.0	30.2	12.3	55.0	1998
Greece	0.25 (1997)	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iceland	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ireland	0.27	91.2	106.0	90.0	10.0	90.3	0	9.8	1998
Italy	0.16 (1996)	74.4	71.8	85.7	14.3	68.4	5.7	19.5	1997
Luxembourg	N/A	21.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Netherlands [6]	0.31	28.3	14.5	47.7	52.3	13.1	36.5	52.3	1998
Norway	0.36	68.0	58.2	68.7	31.3	59.0	17.0	25.0	1997
Portugal	N/A	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A
UK (England and Wales)	0.32	89.5	93	72.1	27.9	86.2	5.7	8.1	1998/99
Spain	0.31 (1996)	75.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Catalonia	0.32	74.6	77.4	95.0	5.0	73.4	20.7	5.9	1998
Sweden	N/A	36.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

1) Quantity of BMW landfilled is stated year as a percentage of BMW produced in 1995.
2) Treatment may not, in all cases, add up to 100 %, due to imbalance between reported production and reported treatment.
3) Relevant year for landfill directive Target Indicator (latest year), collection indicators and treatment indicators.
4) Refers to data for 1995 unless otherwise stated.
5) This figure is derived from the Eurostat baseline for production and landfilling of BMW.
6) Refers to waste from households only.

N/A:No information available

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Topic report 15/2001

Biodegradable municipal waste management in Europe

Part 2: Strategies and instruments, Appendices

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Appendices

Appendix 1: BMW summary flow sheets

Table A1.1	Summary BMW waste flow for Austria

All quantities in tonnes per annum			Management route					
			Landfill	**Incinera-tion with Energy Recov-ery**	**Com-posting**	**Recy-cling**	**Mechan-ical-bio-logical pretreat-ment before landfill**	**Unspeci-fied**
1995								
Municipal waste produced = 2 644 000	Biodegradable municipal waste produced = 1 495 000	Biodegradable municipal waste collected as bagged waste = 600 000	298 000	203 900			92 500	5,600
		Separately collected **FOOD AND GARDEN** waste = 346 000			346 000			
		Separately collected **PAPER** waste = 406 000				406 000		
		Separately collected **TEXTILE** waste =17 000	4 000			13 000		
		Separately collected **WOOD** waste = 20 000		6 100	600	13 300		
		Other (unspecified) biodegradable waste = 106 000 (Note 1)						106,000
TOTAL		**1 495 000**	**302 000**	**210 000**	**346 000**	**432 300**	**92 500**	**111 600**
Percentage			**20.2 %**	**14.0 %**	**23.1 %**	**28.9 %**	**6.2 %**	**7.5 %**
Latest year for which data is available (1996)								
Municipal waste produced = 2 775 000	Biodegradable municipal waste produced = 1 575 000	Biodegradable municipal waste collected as bagged waste = 625 000	317 500	203 300			94 000	10,200
		Separately collected **FOOD AND GARDEN** waste = 360 000			360 000			
		Separately collected **PAPER** waste = 439 000				439 000		
		Separately collected **TEXTILE** waste = 18 000	4 500			13 500		
		Separately collected **WOOD** waste = 22 000		6 700	700	14 600		
		Other (Unspecified) biodegradable waste = 111 000 (Note 1)						111,000
TOTAL		**1 575 000**	**322 000**	**210 000**	**360 000**	**467 100**	**94 000**	**121 200**
Percentage			**20.4 %**	**13.3 %**	**22.9 %**	**29.7 %**	**6.0 %**	**7.7 %**

Note 1: This is thought to consist mainly of bulky biodegradable waste.

Summary BMW waste flow for Baden-Württemburg, Germany Table A1.2

All quantities in tonnes per annum (Note 1)			Management route				
			Landfill	**Incinera-tion with Energy Recovery**	**Biological Treatment**	**Recycling**	**Unspeci-fied**
1995							
Municipal waste produced = 18 300 000	Biodegradable municipal waste produced (Municipal waste containing organics) = 5 858 595	Biodegradable municipal waste collected as bagged waste = 4 101 155	2 486 399	690 222	135 873	773 011	15 650
		Separately collected **FOOD AND GARDEN** waste = 894 744	15 650		792 430		86 664
		Separately collected **PAPER** waste = 733 446				733 446	
		Separately collected **TEXTILE AND SHOES** waste = 12 600				12 600	
		Separately collected **WOOD incl. CORK** waste = 120 200				120 200	
		Separately collected composite **PACKAGING** (Tetrapak) = 11 600				11 600	
		Separately collected waste **FATS** = 500				500	
TOTAL		**5 858 595**	**2 502 049**	**690 222**	**928 303**	**1 651 357**	**102 314**
Percentage			**42.7 %**	**11.8 %**	**15.8 %**	**28.2 %**	**1.7 %**
Latest year for which data is available (1998)							
Municipal waste produced = 14 400 000	Biodegradable municipal waste produced (Municipal waste containing organics) = 5 649 284	Biodegradable municipal waste collected as bagged waste = 3 509 303	1 683 473	690 567	968	1 128 295	6 000
		Separately collected **FOOD AND GARDEN** waste = 1 172 619	21 203	2 091	1 008 069		141 256
		Separately collected **PAPER** waste = 811 062				811 062	
		Separately collected **TEXTILE AND SHOES** waste = 11 700				11 700	
		Separately collected **WOOD incl. CORK** waste = 120 300				120 300	
		Separately collected composite **PACKAGING** (Tetrapak) = 23 900				23 900	
		Separately collected waste **FATS** = 400				400	
TOTAL		**5 649 284**	**1 704 676**	**692 658**	**1 009 037**	**2 095 657**	**147 256**
Percentage			**30.2 %**	**12.3 %**	**17.9 %**	**37.1 %**	**2.6 %**

Note 1: Quantities for BMW produced and quantities originating from the bagged waste fraction relate to all waste handed over to municipalities the biodegradable fraction of which is estimated to be between 31 % and 55 %.

Table A1.3	Summary BMW waste flow for Belgium (Flanders)

All quantities in tonnes per annum			Management route						
			Landfill	**Incineration with Energy Recovery (Note 1)**	**Incineration without Energy Recovery**	**Composting**	**Recycling**	**Anaerobic Digestion**	**Reuse**
1995									
Municipal waste produced = 2 890 221	Biodegradable municipal waste produced = 1 671 108	Biodegradable municipal waste collected as BAGGED waste = 1 022 723 (Note 2)	528 907	493 815					
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = **318 393**				87 279			
		Separately collected **FOOD** waste = 87 279	6 740	269		177 533			
		Separately collected **GARDEN** waste = 231 114	12 983	4 033					46 572
		Not separately collected BULKY GARDEN waste = 17 016 **(Note 3)**							
		Separately collected **PAPER AND PAPERBOARD** waste = 196 741	179				196 562		
		Separately collected **TEXTILE** waste = 3 399					2 287		1 112
		Separately collected **WOOD** waste = 19 442	2 450	1 601		6 825	8 352		214
		BULKY Biodegradable Waste **(other than** garden waste) = 93 394 (Note 3)	71 260	22 135					
TOTAL		**1 671 108**	**622 519**	**521 853**		**271 637**	**207 201**		**47 898**
Percentage			**37.3 %**	**31.2 %**		**16.3 %**	**12.4 %**		**2.9 %**
Latest year for which data is available (1998)									
Municipal waste produced = 3 146 648	Biodegradable municipal waste produced = 1 924 304	Biodegradable municipal waste collected as BAGGED waste = 619 294 (Note 2)	237 666	381 627					
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = 722 016	826			333 211			
		Separately collected **FOOD (Note 4)** waste = 334 038	1 920			318 391	829		66 838
		Separately collected **GARDEN (Note 5)** waste = 387 978	11 934	6 686					
		Not separately collected BULKY GARDEN waste = 18 620 (Note 3)							
		Separately collected **PAPER AND PAPERBOARD** waste = 386 340					386 340		
		Separately collected **TEXTILE** waste = 17 449					4 931		12 519
		Separately collected **WOOD** waste = 58 382	3 812	74		8 321	45 938		237
		BULKY Biodegradable Waste (other than garden waste) = 102 203 (Note 3)	65 503	36 700					
TOTAL		**1 924 304**	**321 661**	**425 087**		**659 923**	**438 038**		**79 594**
Percentage			**16.7 %**	**22.1 %**		**34.3 %**	**22.8 %**		**4.1 %**

Note 1: It is not known which amount of the waste is incinerated with or without energy recovery in 1995.
Note 2: This is counted on percentages based on a report of a sorting analysis of municipal waste of households of 1995-1996.
Note 3: This is counted on percentages based on a report of a sorting analysis of bulky waste of 1998-1999.
Note 4: Food waste in this instance is actually biowaste (VFG – vegetable fruit and (non-woody) garden waste).
Note 5: Garden waste in this instance is vegetational waste – compostable organic waste generated by gardening and maintenance activities in public and private gardens woody materials included.

Summary BMW waste flow for Catalonia SPAIN Table A1.4

All quantities in tonnes per annum			Management Route					
			Landfill	Incineration with Energy Recovery	Composting	Mass Composting (Note 1)	Recycling	Unspecified
1995								
Municipal waste produced = 2 833 945	Biodegradable municipal waste produced = 1 984 912	Biodegradable municipal waste collected as bagged waste = 1 961 524	1 480 609	417 608		62 157		1 150
		Separately collected **PAPER** waste = 23 388					23 388	
TOTAL		**1 984 912**	**1 480 609**	**417 608**		**62 157**	**23 388**	
Percentage			**74.6 %**	**21.0 %**		**3.1 %**	**1.2 %**	**0.1 %**
Latest year for which data is available (1998)								
Municipal waste produced = 2 996 391	Biodegradable municipal waste produced = 2 092 812	Biodegradable municipal waste collected as bagged waste = 1 987 774	1 536 340	433 326		18 108		
		Separately collected **FOOD and GARDEN** waste = 9 096			9 096			
		Separately collected **PAPER** waste = 95 942					95 942	
TOTAL		**2 092 812**	**1 536 340**	**433 326**	**9 096**	**18 108**	**95 942**	
Percentage			**73.4 %**	**20.7 %**	**0.4 %**	**0.9 %**	**4.6 %**	

Note 1: Mass composting refers to the practice of composting biodegradable waste recovered from bagged waste as opposed to composting of biodegradable waste separately collected at source.

Table A1.5 **Summary BMW waste flow for Denmark**

All quantities in tonnes per annum			**Management route**					
			Landfill	**Incineration with Energy Recovery**	**Composting**	**Anaerobic Digestion**	**Recycling**	**Unspecified**
1995								
Municipal waste produced = 2 787 467	Biodegradable municipal waste produced = 1 813 283 (Note 1)	Biodegradable municipal waste collected as bagged waste = 1 184 771	178 745	1 006 026				
		Separately collected **FOOD** waste = 39 000			34 000	5 000		
		Separately collected **GARDEN** waste = 416 182	25 839	11 606	378 736			
		Separately collected **PAPER** waste = 173 330					173 330	
TOTAL		**1 813 283**	**204 584**	**1 017 632**	**412 736**	**5 000**	**173 330**	
Percentage			**11.3 %**	**56.1 %**	**22.8 %**	**0.3 %**	**9.6 %**	
Latest year for which data is available (1998)								
Municipal waste produced = 2 934 747	Biodegradable municipal waste produced = 2 007 213 (Note 1)	Biodegradable municipal waste collected as bagged waste = 1 162 192	81 846	1 080 346				
		Separately collected **FOOD** waste = 51 000			42 000	9 000		
		Separately collected **GARDEN** waste = 585 535	23 869	9 120	552 546			
		Separately collected **PAPER** waste = 208 486					208 486	
TOTAL		**2 007 213**	**105 715**	**1 089 466**	**594 546**	**9 000**	**208 486**	
Percentage			**5.3 %**	**54.3 %**	**29.6 %**	**0.4 %**	**10.4 %**	

Note 1: This figure does not include bulky biodegradable waste.

Summary BMW waste flow for Finland Table A1.6

All quantities in tonnes per annum			Management route						
			Landfill	Incineration with Energy Recovery	Incineration without Energy Recovery	Composting	Recycling	Anaerobic Digestion	Unspecified
1994									
Municipal waste produced =2 100 000	Biodegradable Municipal waste produced = 1 664 000	Biodegradable municipal waste collected as **BAGGED** waste = 978 000	928 000	50 000					
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = 70 000 Separately collected **FOOD** waste = Separately collected **GARDEN** waste =				70 000			
		Separately collected **PAPER AND PAPERBOARD** waste = 392 000					392 000		
		BULKY Biodegradable Waste (other than garden waste) = 224 000	156 800				67 200		
TOTAL		**1 664 000**	**1 084 800**	**50 000**		**70 000**	**459 200**		
Percentage			**65.2 %**	**3.0 %**		**4.2 %**	**27.6 %**		
Latest year for which data is available (1997)									
Municipal waste produced = 2 510 000	Biodegradable municipal waste produced = 1 780 745	Biodegradable municipal waste collected as **BAGGED waste** = 1 258 400	1 153 400	80 000				25 000	
		Separately collected FOOD waste and **GARDEN waste** TOTAL = 93 376 Separately collected **FOOD** waste = Separately collected **GARDEN** waste =				93 376			
		Separately collected **PAPER AND CARDBOARD** waste = 350 591	382	385			349 824		
		Separately collected **PACKAGING** waste **=** 52 116	1 391	17 996			23 316		9 413 (R13 Storage)
		Separately collected **WOOD** waste = 26 262	245	5 790			19 320		907 (R13 Storage)
		BULKY Biodegradable Waste (other than garden waste) (Note 1)							
TOTAL		**1 780 745**	**1 155 418**	**104 171**		**93 376**	**392 460**	**25 000**	**10 320**
Percentage			**64.9 %**	**5.8 %**		**5.2 %**	**22.0 %**	**1.4 %**	**0.6 %**

Note 1: Method of classification changes between 1994 and 1997: the term 'bulky waste' is no longer used in Finland.

Table A1.7 Summary BMW waste flow for France

All quantities in tonnes per annum			**Management route**						
			Landfill	**Incineration with Energy Recovery**	**Incineration without Energy Recovery**	**Composting**	**Recycling**	**Anaerobic Digestion**	**Unspecified**
1995									
Municipal waste produced = 36 200 000	Biodegradable Municipal waste produced = 15 746 376	Biodegradable municipal waste collected as BAGGED waste = 12 996 376	5 854 855	4 273 331	1 628 866	1 030 361	165 844	43 119	
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = Separately collected **FOOD** waste = 0 Separately collected **GARDEN** waste = 2 530 000	133 500	5 000	5 300	516 000			1 870 200
		Separately collected **PAPER AND PAPERBOARD** waste = 220 000					220 000		
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL		**15 746 376**	**5 988 355**	**4 278 331**	**1 634 166**	**1 546 361**	**385 844**	**43 119**	**1 870 200**
Percentage			**38.0 %**	**27.1 %**	**10.4 %**	**9.8 %**	**2.4 %**	**0.3 %**	**11.9 %**
Latest year for which data is available (1998)									
Municipal waste produced = 38 000 000	Biodegradable municipal waste produced = 16 724 000	Biodegradable municipal waste collected as BAGGED waste = 13 680 000	6 608 614	4 784 806	1 192 955	973 432	71 625	48 568	
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = Separately collected **FOOD** waste = 60 000 Separately collected **GARDEN** waste = 2 530 000	133 500	5 000	5 300	516 000	60 000		1 870 200
		Separately collected **PAPER AND PAPERBOARD** waste = 454 000					454 000		
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL		**16 724 000**	**6 742 114**	**4 789 806**	**1 198 255**	**1 489 432**	**585 625**	**48 568**	**1 870 200**
Percentage			**40.3 %**	**28.6 %**	**7.1 %**	**8.9 %**	**3.5 %**	**0.3 %**	**11.2 %**

Summary BMW waste flow for Germany Table A1.8

All quantities in tonnes per annum			Management route						
			Landfill	Incineration with Energy Recovery	Incineration without Energy Recovery	Composting	Recycling	Anaerobic Digestion	Unspecified
1993									
Municipal waste produced = 43 486 000	Biodegradable municipal waste produced = 12 000 000 (Note 1)	Biodegradable municipal waste collected as BAGGED waste =							
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = Separately collected **FOOD** waste = Separately collected **GARDEN** waste =							
		Separately collected PAPER and PAPERBOARD waste = 4 649 000 (Note 2)					4 649 000		
		Separately collected biodegradable waste (Total) = 2 823 000 (Note 3)							
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL						**2 571 000**	**4 649 000**		
Percentage									
Latest year for which data is available (1998)									
Municipal waste produced =	Biodegradable municipal waste produced =	Biodegradable municipal waste collected as BAGGED waste =	27 000 000	8 500 000					1 600 000
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = Separately collected **FOOD** waste = Separately collected **GARDEN** waste =							
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL						**7 500 000**			
Percentage									

Note 1: Approximate quantity of biodegradable waste from households only.
Note 2: Management route for separately collected paper and paperboard is not specified.
Note 3: All this quantity is delivered to civic waste facilities but the management route is not specified.

Table A1.9	Summary BMW waste flow for Greece

All quantities in tonnes per annum			Management route						
			Land-fill	Incin-era-tion with Ener-gy Re-covery	Incin-era-tion with-out En-ergy Recov-ery	Com-post-ing	Recy-cling	Anaer-obic Diges-tion	Un-speci-fied
Municipal waste produced =	Biodegrada ble municipal waste produced =	Biodegradable municipal waste collected as BAGGED waste =							
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = Separately collected **FOOD** waste = Separately collected **GARDEN** waste =							
		Separately collected **PAPER AND PAPERBOARD** waste =							
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL									
Percentage									
Latest year for which data is available (1997)									
Municipal waste produced = 3 900 000	Biodegrad-able municipal waste produced = 2 613 000	Biodegradable municipal waste collected as BAGGED waste =2 324 100							
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = 31 500 Separately collected **FOOD** waste = Separately collected **GARDEN** waste =				31 500			
		Separately collected **PAPER AND PAPERBOARD** waste = 257 400					257 400		
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL		**2 613 000**				**31 500**	**257 400**		
Percentage						**1.2 %**	**9.9 %**		

Note 1: 47 % of total municipal waste is organic (780 000 tonnes) of which 1.72 % is composted (31 500 tonnes).
Note 2: 20 % of total municipal waste is paper (1 833 000 tonnes) of which 33 % is recycled (257 000 tonnes).

It must be noted that the above factors are derived from average composition of domestic waste and may not be directly comparable with municipal waste.

Summary BMW waste flow for Iceland (No Information) Table A1.10

All quantities in tonnes per annum			**Management route**						
			Land-fill	**Incin-eration with Energy Recovery**	**Incin-eration without Energy Recovery**	**Com-posting**	**Recy-cling**	**Anaerobic Di-gestion**	**Un-speci-fied**
Municipal waste produced =	Biodegradable municipal waste produced =	Biodegradable municipal waste collected as BAGGED waste =							
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = Separately collected **FOOD** waste = Separately collected **GARDEN** waste =							
		Separately collected **PAPER AND PAPERBOARD** waste =							
		OTHERS (PLEASE SPECIFY) Separately collected waste =							
		OTHERS (PLEASE SPECIFY) Separately collected waste =							
		OTHERS (PLEASE SPECIFY) Separately collected waste =							
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL									
Percentage									
Latest year for which data is available ()									
Municipal waste produced =	Biodegradable municipal waste produced =	Biodegradable municipal waste collected as BAGGED waste =							
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = Separately collected **FOOD** waste = Separately collected **GARDEN** waste =							
		Separately collected **PAPER AND PAPERBOARD** waste =							
		OTHERS (PLEASE SPECIFY) Separately collected waste =							
		OTHERS (PLEASE SPECIFY) Separately collected waste =							
		OTHERS (PLEASE SPECIFY) Separately collected waste =							
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL									
Percentage									

Table A1.11	Summary BMW waste flow for Ireland

All quantities in tonnes per annum			Management Route		
			Landfill	**Composting**	**Recycling**
1995					
Municipal waste produced = 1 503 171	Biodegradable municipal waste produced = 990 242	Biodegradable municipal waste collected as bagged waste = 902 712	902 712		
		Separately collected **FOOD** waste = 30		30	
		Separately collected **PAPER** waste = 84 000			84 000
		Separately collected **TEXTILE** waste = 3 500			3 500
		Separately collected **WOOD** waste = 0			
TOTAL		**990 242**	**902 712**	**30**	**87 500**
Percentage			**91.2 %**	**0.0 %**	**8.8 %**
Latest year for which data is available (1998)					
Municipal waste produced = 1 852 450	Biodegradable municipal waste produced = 1 162 218	Biodegradable municipal waste collected as bagged waste = 1 049 005	1 049 005		
		Separately collected **FOOD** waste = 5 664		5 664	
		Separately collected **PAPER** waste = 94 302			94 302
		Separately collected **TEXTILE** waste = 3 247			3 247
		Separately collected **WOOD** waste = 10 000			10 000
TOTAL		**1 162 218**	**1 049 005**	**5 664**	**107 549**
Percentage			**90.3 %**	**0.5 %**	**9.3 %**

Summary BMW waste flow for Italy Table A1.12

All quantities in tonnes per annum			Management route					
			Landfill	**Incineration with/ without Energy Recovery**	**Composting**	**Anaerobic Digestion**	**Recycling**	**Unspecified**
1996								
Municipal waste produced = 25 959 990	Biodegradable municipal waste produced = 9 170 530	Biodegradable municipal waste collected as bagged waste = 8 217 940 (Note 1)	6 820 890	493 076	328 718			575 256
		Separately collected **FOOD** and **GARDEN** waste TOTAL = 376 100 Separately collected **FOOD** waste = Separately collected **GARDEN** waste =			376 100			
		Separately collected **PAPER** waste = 576 490					576 490	
TOTAL		**9 170 530**	**6 820 890**	**493 076**	**704 818**		**576 490**	**575 256**
Percentage			**74.4 %**	**5.4 %**	**7.7 %**		**6.3 %**	**6.3 %**
1997								
Municipal waste produced = 26 605 200	Biodegradable municipal waste produced = 9 623 889	Biodegradable municipal waste collected as bagged waste = 8 243 063 (Note 1)	6 586 207	544 042	494 584			618 230
		Separately collected **FOOD** and **GARDEN** waste TOTAL = 598 342 Separately collected **FOOD** waste = Separately collected **GARDEN** waste =			598 342			
		Separately collected **PAPER** waste = 782 484					782 484	
TOTAL		**9 623 889**	**6 586 207**	**544 042**	**1 092 926**		**782 484**	**618 230**
Percentage			**68.4 %**	**5.7 %**	**11.4 %**		**8.1 %**	**6.4 %**
Latest year for which data is available (1998)								
Municipal waste produced = 26 845 726	Biodegradable municipal waste produced = 10 092 409	Biodegradable municipal waste collected as bagged waste = 8 200 266 (Note 1)	6 347 005	598 619				
		Separately collected **FOOD** and **GARDEN** waste TOTAL = 891 150 Separately collected **FOOD** waste = Separately collected **GARDEN** waste =			891 150			
		Separately collected **PAPER** waste = 1 000 993					1 000 993	
TOTAL		**10 092 409**	**6 347 005**	**598 619**	**891 150**		**1 000 993**	
Percentage			**62.9 %**	**5.9 %**	**8.8 %**		**9.9**	

Note 1: Estimation made considering an average percentage of BMW equal to 50 % of bagged MW (paper waste included).

Table A1.13 **Summary BMW waste flow for Luxembourg (No Information)**

All quantities in tonnes per annum			**Management route**						
			Landfill	**Incineration with Energy Recovery**	**Incineration without Energy Recovery**	**Composting**	**Recycling**	**Anaerobic Digestion**	**Unspecified**
Municipal waste produced =	Biodegradable municipal waste produced =	Biodegradable municipal waste collected as BAGGED waste =							
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = Separately collected **FOOD** waste = Separately collected **GARDEN** waste =							
		Separately collected **PAPER AND PAPERBOARD** waste =							
		OTHERS (PLEASE SPECIFY) Separately collected waste =							
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL									
Percentage									
Latest year for which data is available ()									
Municipal waste produced =	Biodegradable municipal waste produced =	Biodegradable municipal waste collected as BAGGED waste =							
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = Separately collected **FOOD** waste = Separately collected **GARDEN** waste =							
		Separately collected **PAPER AND PAPERBOARD** waste =							
		OTHERS (PLEASE SPECIFY) Separately collected waste =							
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL									
Percentage									

Summary BMW waste flow for Norway Table A1.14

All quantities in tons per annum			Management route						
			Landfill	Incineration with Energy Recovery	Incineration without Energy Recovery	Composting	Recycling	Anaerobic Digestion	Unspecified
1995									
Municipal waste produced = 2 722 000	Biodegradable municipal waste produced = 1 571 607	Biodegradable municipal waste collected as BAGGED waste = 1 285 437							
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = 67 479 Separately collected **FOOD** waste = 34 399 Separately collected **GARDEN** waste = 33 080							
		Separately collected **PAPER AND PAPERBOARD** waste = 169 700							
		Separately collected **TEXTILE** waste = 4 101							
		BULKY Biodegradable Waste (other than garden waste) WOOD waste = 44 890							
TOTAL		**1 571 607**	**1 068 693**	**282 889**		**15 716**	**204 309**		
Percentage			**68.0 %**	**18.0 %**		**1.0 %**	**13.0 %**		
Latest year for which data is available (1997) (Note 1)									
Municipal waste produced = 2 720 740	Biodegradable Municipal waste produced = 1 550 000	Biodegradable municipal waste collected as BAGGED waste = 1 064 577							
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = 121 123 Separately collected **FOOD** waste = 79 900 Separately collected **GARDEN** waste = 73 000							
		Separately collected **PAPER AND PAPERBOARD** waste = 279 600							
		Separately collected **TEXTILE** waste = 7 400							
		BULKY Biodegradable Waste (other than garden waste) WOOD waste = 77 300							
TOTAL		**1 550 000**	**914 500**	**263 500**		**77 500**	**310 000**		
Percentage			**59.0 %**	**17.0 %**		**5.0 %**	**20.0 %**		

Note 1: Norsas can provide total figures for 1998 but the figures from 1997 are more detailed. The change of amounts from 1997-1998 is of no significance.

Tabel A1.15 **Summary BMW waste flow for Portugal**

All quantities in tonnes per annum			**Management route**						
			Land fill	**Incineration with Energy Recovery**	**Incineration without Energy Recovery**	**Composting**	**Recycling**	**Anaerobic Digestion**	**Reuse**
1995									
Municipal waste produced = 3 340 000	Biodegradable municipal waste produced =	Biodegradable municipal waste collected as BAGGED waste =							
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL =							
		Separately collected **FOOD** waste =							
		Separately collected **GARDEN** waste =							
		Separately collected **PAPER AND PAPERBOARD** waste =					3 116		
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL									
Percentage									
Latest year for which data is available (1998)									
Municipal waste produced = 4 173 252	Biodegradable municipal waste produced =	Biodegradable municipal waste collected as BAGGED waste =				183 761			
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL =							
		Separately collected **FOOD** waste =							
		Separately collected **GARDEN** waste =14 314				14 314			
		Separately collected **PAPER AND PAPERBOARD** waste =					433 000		
		Separately collected **TEXTILE** waste = 134							134
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL									
Percentage									

Summary BMW waste flow for Spain Table A1.16

All quantities in tonnes per annum			Management route						
			Landfill	Incineration with Energy Recovery	Incineration without Energy Recovery	Composting	Recycling	Anaerobic Digestion	Recovery
1995									
Municipal waste produced =	Biodegradable municipal waste produced =	Biodegradable municipal waste collected as BAGGED waste =							
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = Separately collected **FOOD** waste = Separately collected **GARDEN** waste =							
		Separately collected **PAPER AND PAPERBOARD** waste =							
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL									
Percentage									
Latest year for which data is available (1996) (Note 1)									
Municipal waste produced = 17 175 186	Biodegradable municipal waste produced = 12 196 099	Biodegradable municipal waste collected as BAGGED waste =							
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = Separately collected **FOOD** waste = Separately collected **GARDEN** waste =							
		Separately collected **PAPER waste =**					950 000		
		Separately collected **PAPER and CARDBOARD PACKAGING waste =**					1 175 000		
		Separately collected **WOOD PACKAGING** waste =					34 200		
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL									
Percentage									

Note 1: Source: Plan Nacional De Residuos Urbanos (2000-2006)

Table A1.17 **Summary BMW waste flow for Sweden**

All quantities in tonnes per annum			**Management route**						
			Land-fill	**Incin-era-tion with Ener-gy Re-covery**	**Incin-era-tion with-out Ener-gy Re-covery**	**Com-post-ing**	**Recycling**	**Anaer-obic Diges-tion**	**Un-speci-fied**
1995									
Municipal waste produced =	Biodegradable municipal waste produced =	Biodegradable municipal waste collected as BAGGED waste =							
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = Separately collected **FOOD** waste = Separately collected **GARDEN** waste =							
		Separately collected **PAPER AND PAPERBOARD** waste =							
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL									
Percentage									
Latest year for which data is available (1998)									
Municipal waste produced = 4 000 000 (Note 1)	Biodegradable municipal waste produced =	Biodegradable municipal waste collected as BAGGED waste =							
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = Separately collected **FOOD** waste = Separately collected **GARDEN** waste =							
		Separately collected **PAPER AND PAPERBOARD** waste =					435 000 (Note 2)		
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL									
Percentage									

Summary BMW waste flow for The Netherlands Table A1.18

All quantities in tonnes per annum			Management route						
			Landfill	Incineration with Energy Recovery	Incineration without Energy Recovery	Composting	Recycling	Anaerobic Digestion	Unspecified
1995									
Waste from households (household waste + bulky household waste) = 7 105 000	Biodegradable municipal waste produced from households = 4 830 000 only garden/food waste and paper waste have been considered	Biodegradable waste from households collected as mixed waste = 2 520 000	1 265 000	1 255 000					
		Separately collected household **FOOD** waste and **GARDEN** waste TOTAL = 1 575 000 Separately collected small **FOOD + garden** waste = 1 450 000 Separately collected bulky **GARDEN** waste = 125 000	110 000			1 450 000 125 000			
		Separately collected household **PAPER AND PAPERBOARD** waste = 735 000					735 000		
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL		**4 830 000**	**1 365 000**	**1 255 000**		**1 575 000**	**735**		
Percentage (Note 1)			**28.3 %**	**26 %**		**33.3 %**	**15.2 %**		
Latest year for which data is available (1998)									
Waste from households (household waste + bulky household waste)= 8 060 000	Biodegradable municipal waste produced from households = 5 340 000 only garden/food waste and paper waste have been considered	Biodegradable waste from households collected as mixed waste = 2 545 000	605 000	1 940 000					
		Separately collected household **FOOD** waste and **GARDEN** waste TOTAL = 1 780 000 Separately collected small **FOOD + garden** waste = 1 490 000 Separately collected bulky **GARDEN** waste = 290 000	95 000	10 000		1 490 000 290 000			
		Separately collected household **PAPER AND PAPERBOARD** waste = 1 015 000					1 015 000		
		BULKY Biodegradable Waste (other than garden waste) =							
TOTAL		**5 340 000**	**700 000**	**1 950 000**		**1 780 000**	**1 015 000**		
Percentage (Note 1)			**13.1 %**	**36.5 %**		**33.3 %**	**19.0 %**		

Note 1: From the residue of composting of small food and garden waste (105 000 tonnes in 1998) 95 000 tonnes was landfilled and 10 000 tonnes incinerated. This also causes the adding up to 102 %. The same is for 1995

Supplementary information
Wood (1 3 % of total household waste and a much higher but not exactly known percentage of bulky household waste) has not been taken in consideration. Besides household waste and bulky household waste there is one more waste stream that can be considered to be completely 'municipal'. This is public cleansing waste (sweeping waste market waste public garden waste etc.) a stream completely collected by the municipalities. In 1995 the total amount was 965 000 tonnes. Of this amount 480 000 tonnes of public garden and other green waste was collected separately. 360 000 tonnes of this was composted 100 000 tonnes landfilled and the rest directly recycled.In 1998 the total amount was 1 010 000 tonnes. Of this amount 540 000 tonnes of public garden and other green waste was collected separately. 500 000 tonnes of this was composted 15 000 tonnes landfilled and the rest incinerated or directly recycled.

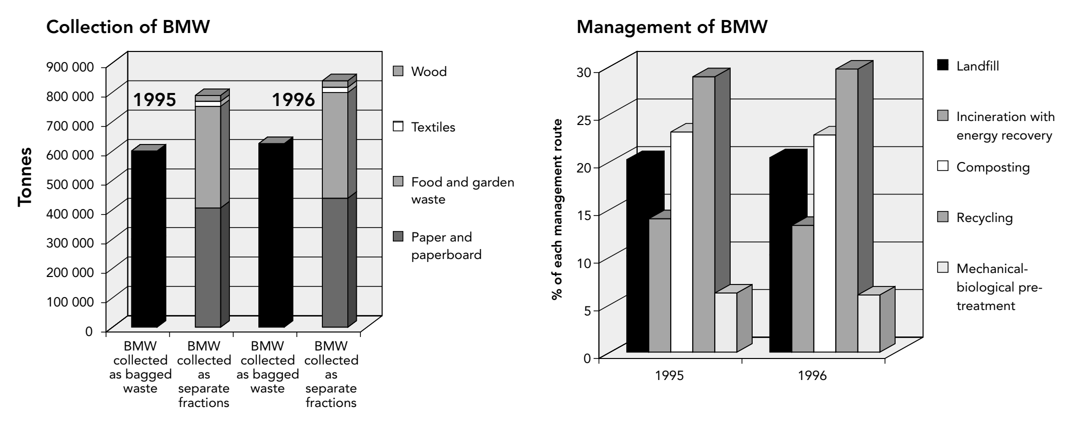
The total amount of waste from the commercial and service sector (in the Netherlands we are talking about the waste stream: 'office shop and services waste'; it does not include any industrial businesses) in 1998 was estimated at 3 370 000 tonnes. Please note: only a small part of this amount is collected by or on behalf of the municipalities and can be considered as municipal waste. It was estimated that this waste stream contains about 1 330 000 tonnes of waste paper and cardboard 830 000 tonnes of which was separately collected and recycled. Of the remaining 500 000 tonnes about 200 000 tonnes has been incinerated and 300 000 tonnes landfilled The total amount of biodegradable organic waste (food garden and the like) in this waste stream is not well known but a rough estimate would be 600 000–800 000 tonnes of which 100 000–200 000 tonnes will be composted.

Summary BMW waste flow for the United Kingdom (England and Wales) — Table A1.19

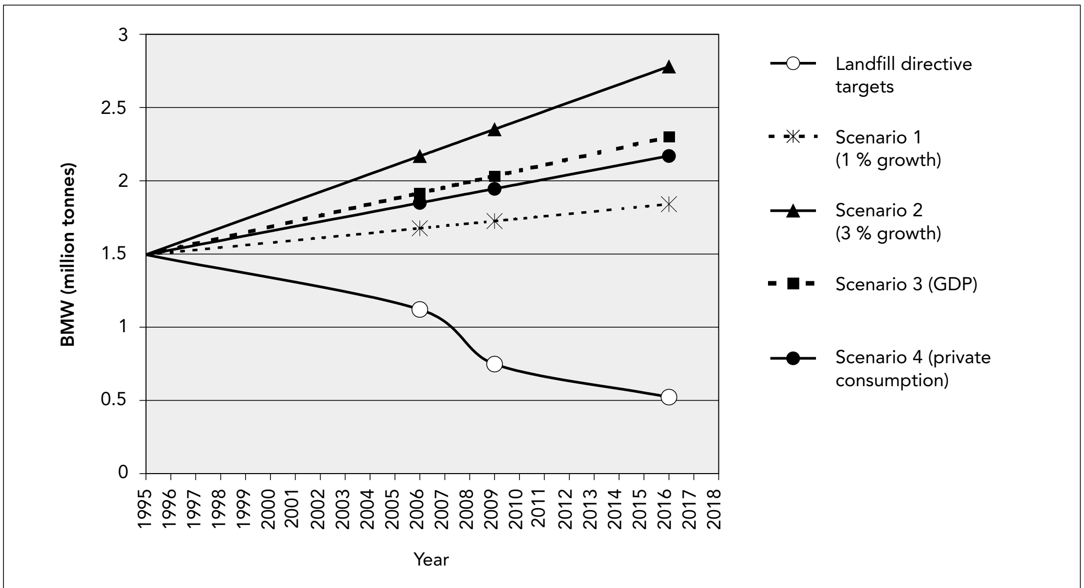
All quantities in tonnes per annum			Management route: Landfill	Incineration with Energy Recovery	Incineration without Energy Recovery	Composting	Recycling	Anaerobic Digestion	Unspecified
1996/97									
Municipal waste produced = 25 980 000	Biodegradable municipal waste produced = 16 366 000 No official UK data; calculated from composition of dustbin and civic amenity waste. Bagged waste figure calculated from composition of dustbin waste minus amounts recycled or composted.	Biodegradable municipal waste collected as BAGGED waste = 12 300 000	11 550 000	750 000					
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = 282 000 Separately collected **FOOD** waste = 21 000 Separately collected **GARDEN** waste = 261 000				21 000 261 000			
		Separately collected **PAPER AND PAPERBOARD** waste = 625 000					625 000		
		Separately collected **TEXTILE** waste = 34 000					34 000		
		OTHER garden waste not separated for composting at civic amenity sites = 2 225 000	2 225 000						
		BULKY Biodegradable Waste (not garden waste not separated at CA sites = 900 000	900 000						
TOTAL		**16 366 000**	**14 675 000**	**750 000**		**282 000**	**659 000**		
Percentage			**89.7 %**	**4.6 %**		**1.7 %**	**4.0 %**		
Latest year for which data is available (1998/99)									
Municipal waste produced = 27 990 000	Biodegradable municipal waste produced = 17 682 000 No official UK data; calculated from composition of dustbin and civic amenity waste. Bagged waste figure calculated from composition of dustbin waste minus amounts recycled or composted.	Biodegradable municipal waste collected as BAGGED waste = 12 750 000	11 750 000	1 000 000					
		Separately collected **FOOD** waste and **GARDEN** waste TOTAL = 525 000 Separately collected **FOOD** waste = 33 000 Separately collected **GARDEN** waste = 492 000				33 000 492 000			
		Separately collected **PAPER AND PAPERBOARD** waste = 864 000					864 000		
		OTHER garden waste not separated for composting at civic amenity sites = 2 500 000	2 500 000						
		Separately collected TEXTILE waste = 43 000					43 000		
		Other bulky Biodegradable Waste (not garden waste) not separated at CA sites = 1 000 000	1 000 000						
TOTAL		**17 682 000**	**15 250 000**	**1 000 000**		**525 000**	**907 000**		
Percentage			**86.2 %**	**5.7 %**		**3.0 %**	**5.1 %**		

Appendix 2:
BMW management status sheets

Existing collection and management of BMW in Austria A2.1



Future projections A2.2

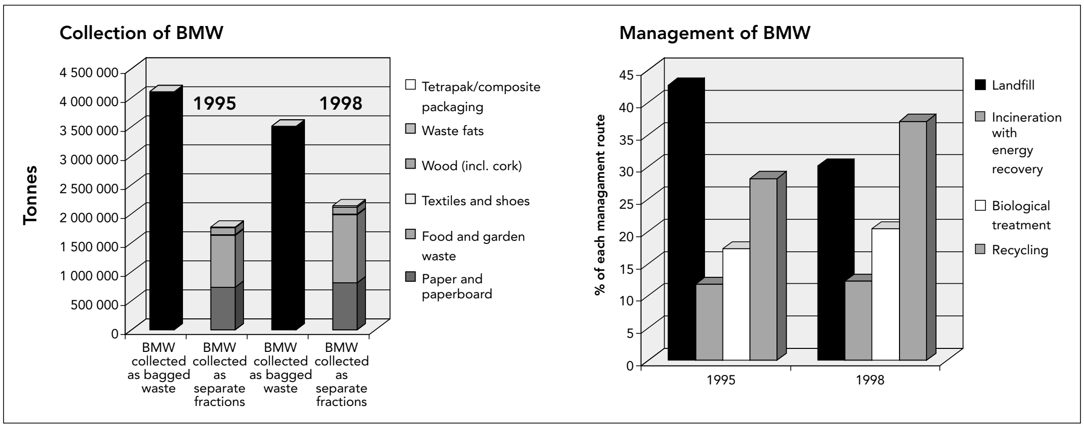


Landfill directive targets and capacity requirements A2.3

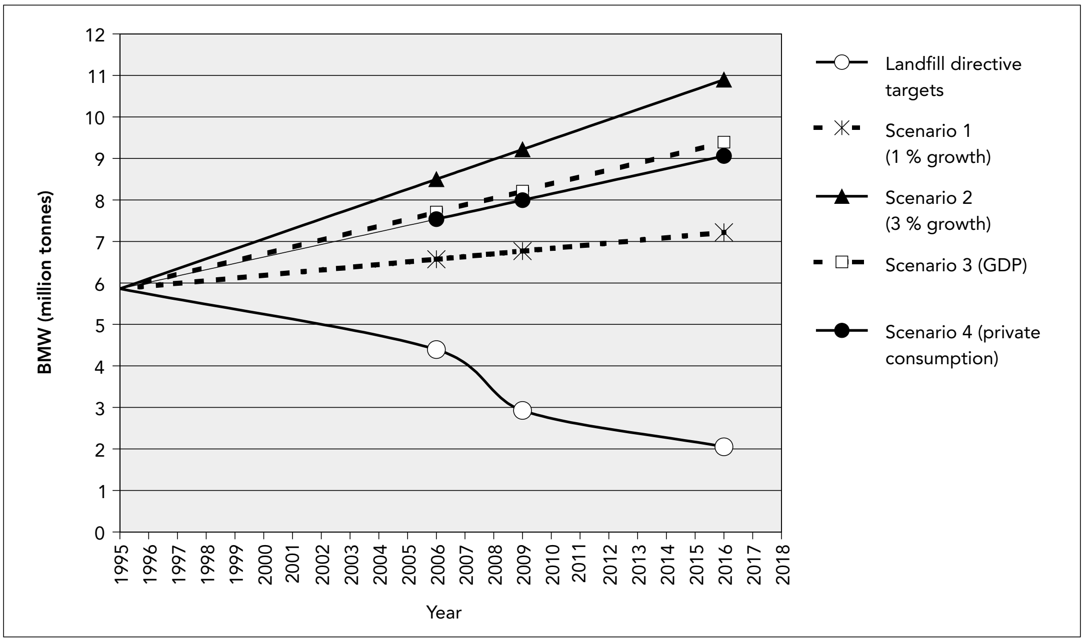
Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	1.495		
1996	1.575		
GDP 2006	1.87	1.121	0.749
2009	1.99	0.748	1.242
2016	2.3	0.523	1.777
Private consumption 2006	1.82	1.121	0.699
2009	1.92	0.748	1.172
2016	2.17	0.523	1.647

Capacity requirements based on GDP and private consumption

A2.4	Existing collection and management of BMW in Baden-Württemberg



A2.5	Future projections

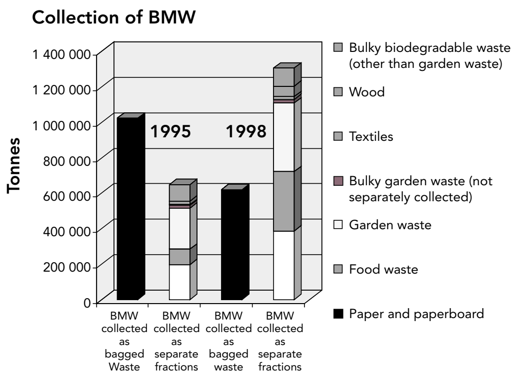


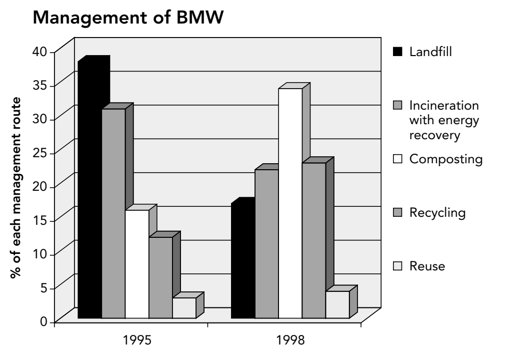
A2.6	Landfill directive targets and capacity requirements

Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	5.859		
1998	5.649		
GDP 2006	7.502	4.39	3.112
2009	8.025	2.93	5.095
2016	9.392	2.05	7.342
Private consumption 2006	7.362	4.39	2.972
2009	7.835	2.93	4.905
2016	9.060	2.05	7.01

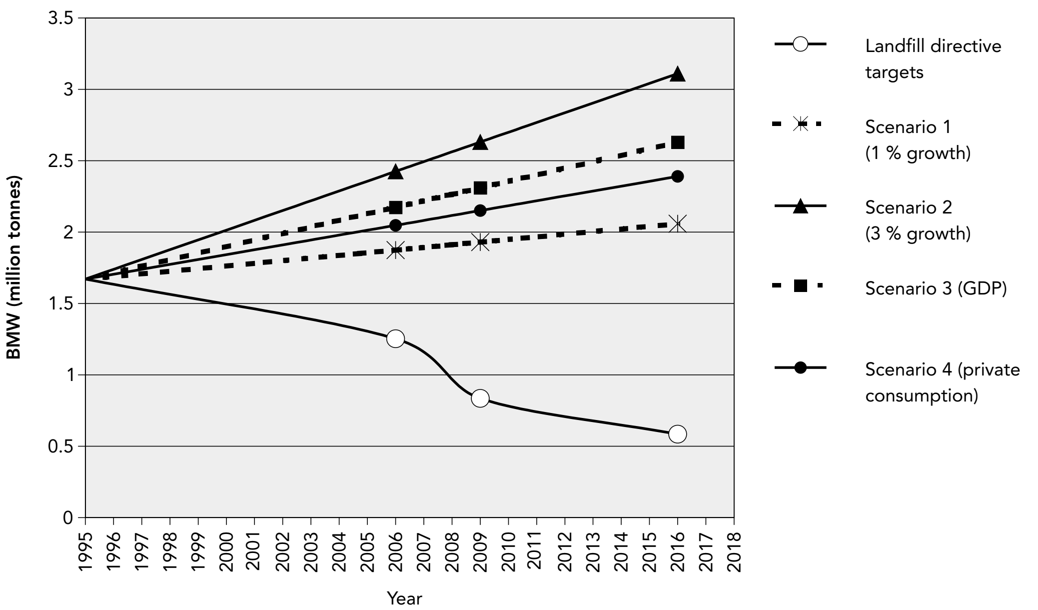
Capacity requirements based on GDP and private consumption

Existing collection and management of BMW in the Flemish Region of Belgium (Flanders) A2.7





Future projections A2.8

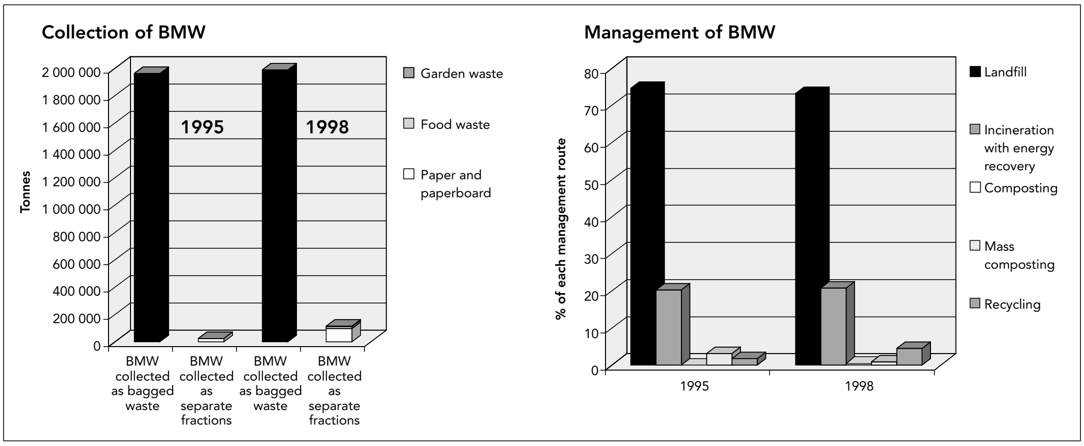


Landfill directive targets and capacity requirements A2.9

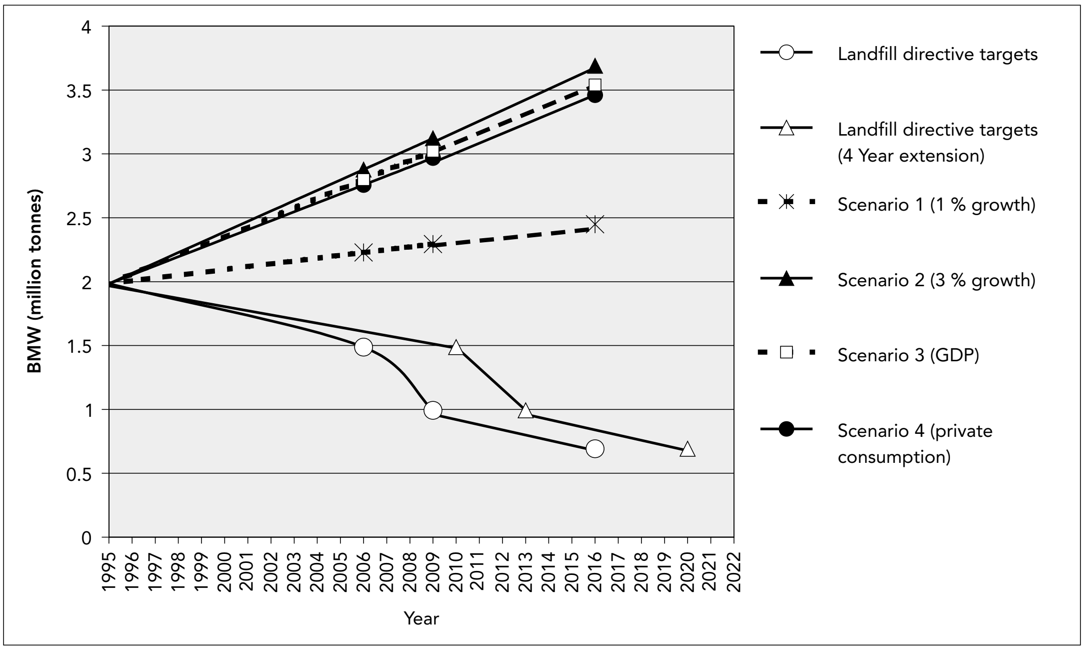
Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	1.671		
1998	1.924		
GDP 2006	2.12	1.253	0.867
2009	2.26	0.836	1.424
2016	2.63	0.585	2.045
Private consumption 2006	2.02	1.253	0.767
2009	2.12	0.836	1.284
2016	2.39	0.585	1.805

Capacity requirements based on GDP and private consumption

A2.10	**Existing collection and management of BMW in Catalonia**



A2.11	**Future projections**

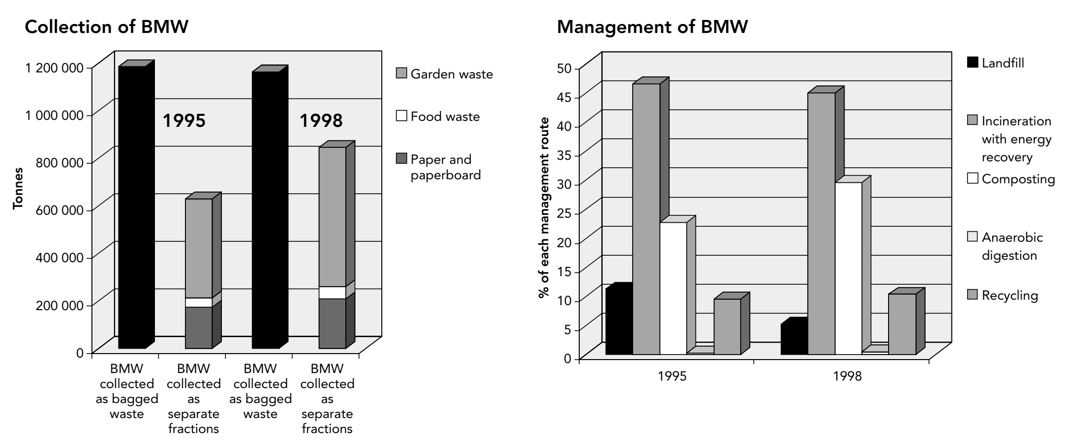


A2.12	**Landfill directive targets and capacity requirements**

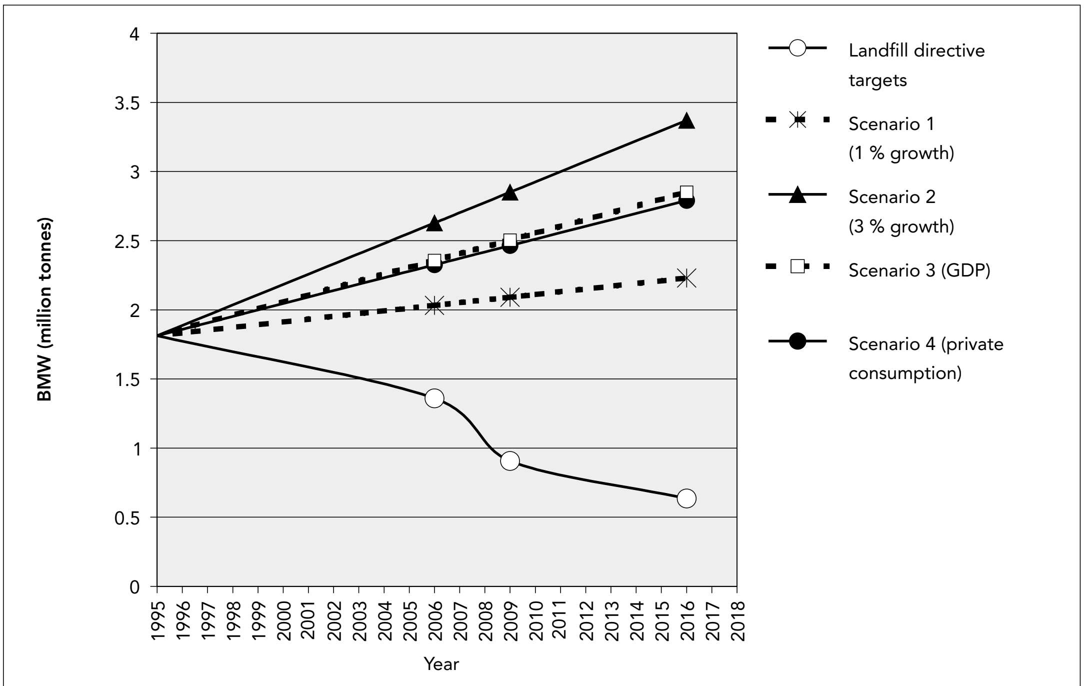
Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	1.984		
1998	2.097		
GDP			
2006	2.69	1.488	1.202
2009	2.92	0.992	1.928
2016	3.54	0.692	2.484
Private consumption			
2006	2.66	1.488	1.172
2009	2.88	0.992	1.888
2016	3.46	0.692	2.768

Capacity requirements based on GDP and private consumption

Existing collection and management of BMW in Denmark — A2.13



Future projections — A2.14

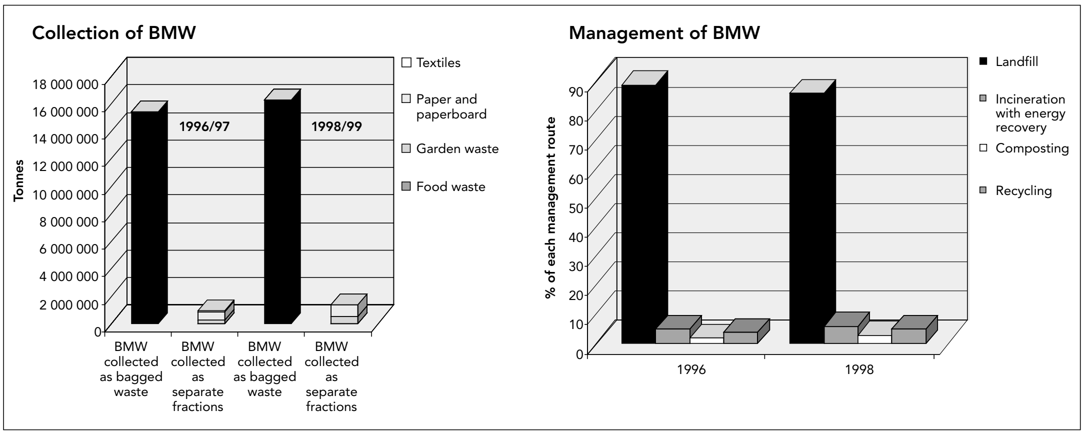


Landfill directive targets and capacity requirements — A2.15

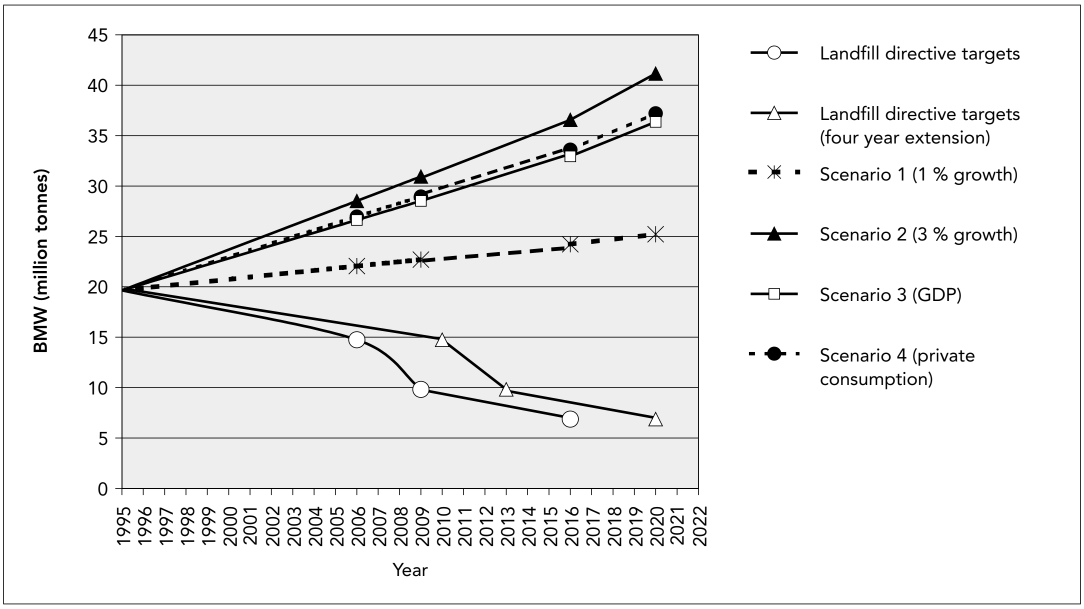
Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	1.813		
1998	2.007		
GDP			
2006	2.30	1.36	0.94
2009	2.45	0.907	1.543
2016	2.85	0.635	2.215
Private consumption			
2006	2.27	1.36	0.91
2009	2.42	0.907	1.513
2016	2.79	0.635	2.155

Capacity requirements based on GDP and private consumption

A2.16 Existing collection and management of BMW in England and Wales



A2.17 Future projections



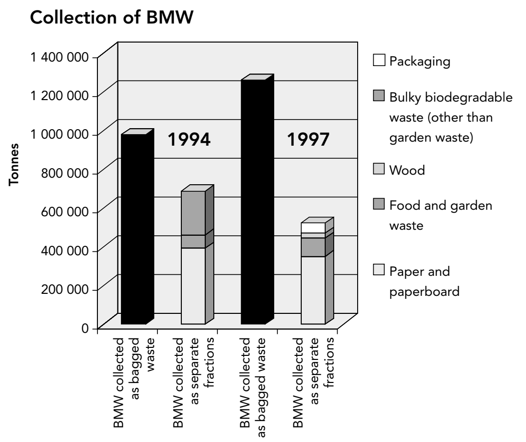
A2.18 Landfill directive targets and capacity requirements

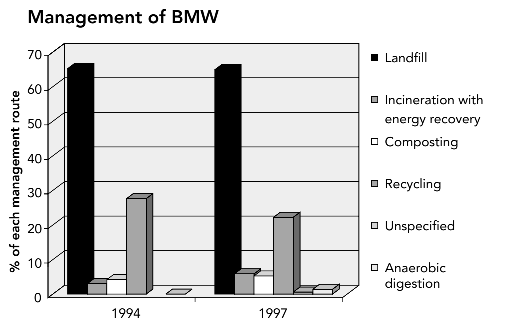
Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	19.66[1]		
1998	17.7		
GDP 2006	25.77	14.745	11.025
2009	27.74	9.83	17.91
2016	32.95	6.881	26.069
Private consumption 2006	26.03	14.745	11.285
2009	28.10	9.83	18.27
2016	33.60	6.881	26.719

1 **Source:** Eurostat

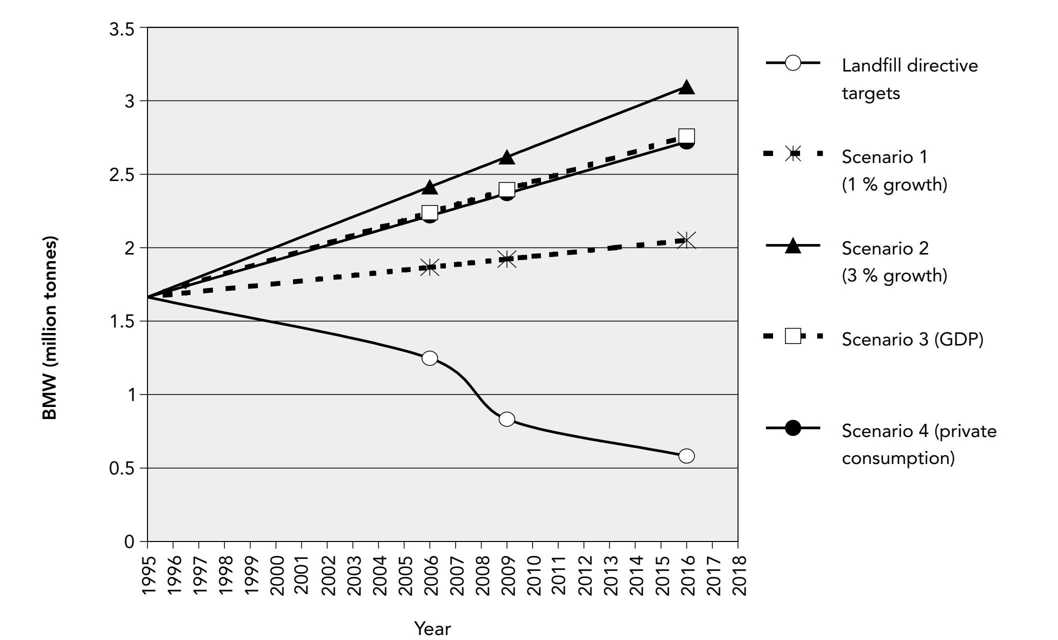
Capacity requirements based on GDP and private consumption

Existing collection and management of BMW in Finland — A2.19





Future projections — A2.20

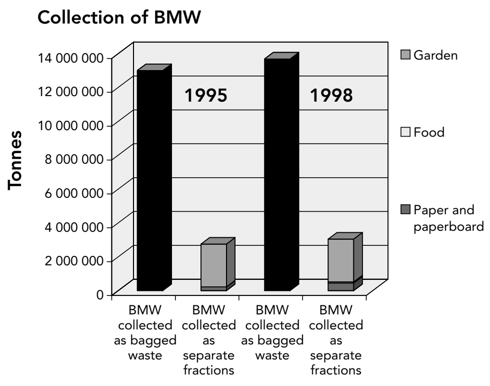


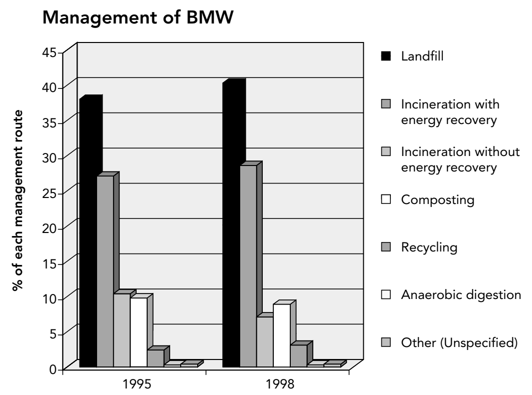
Landfill directive targets and capacity requirements — A2.21

Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1994	1.664		
1997	1.781		
GDP 2006	2.17	1.248	0.922
2009	2.33	0.832	1.498
2016	2.76	0.582	2.178
Private consumption 2006	2.15	1.248	0.902
2009	2.31	0.832	1.478
2016	2.72	0.582	2.138

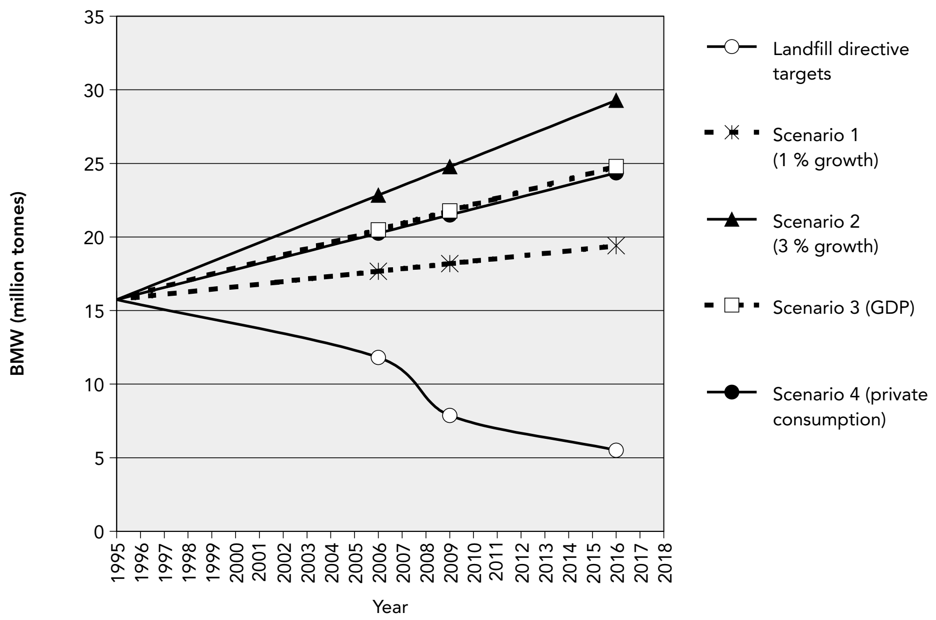
Capacity requirements based on GDP and private consumption

A2.22 Existing collection and management of BMW in France





A2.23 Future projections

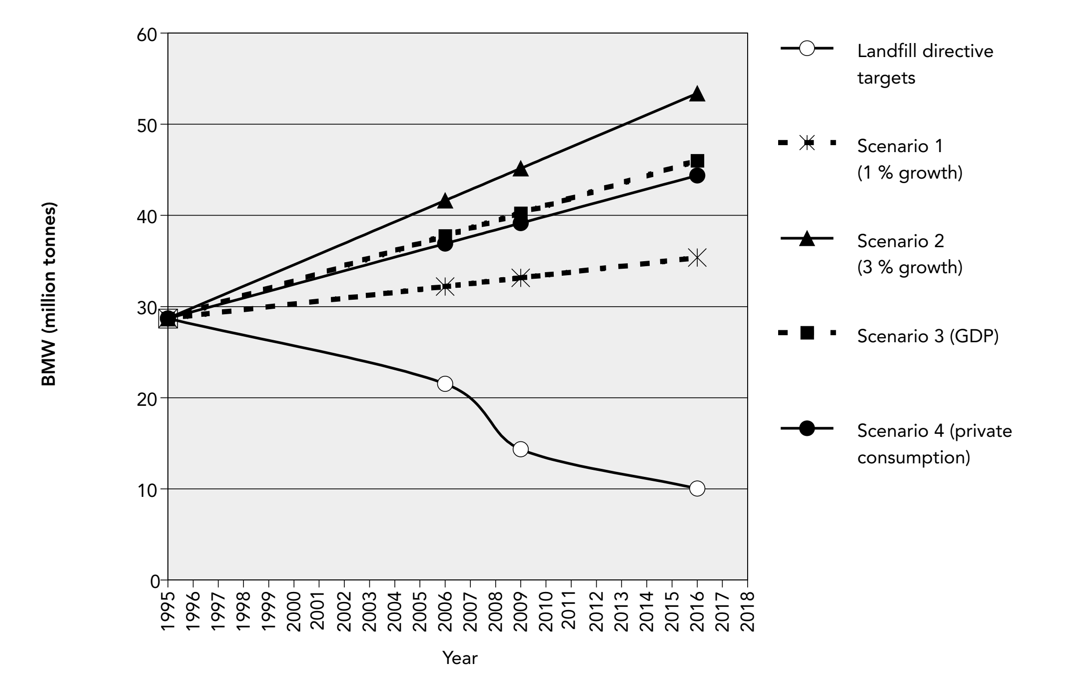


A2.24 Landfill directive targets and capacity requirements

Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	15.746		
1998	16.724		
GDP			
2006	19.97	11.810	8.160
2009	21.31	7.873	13.437
2016	24.79	5.520	19.270
Private consumption			
2006	19.79	11.810	8.169
2009	21.06	7.873	13.187
2016	24.36	5.511	18.849

Capacity requirements based on GDP and private consumption

Future projections for BMW production in Germany A2.25



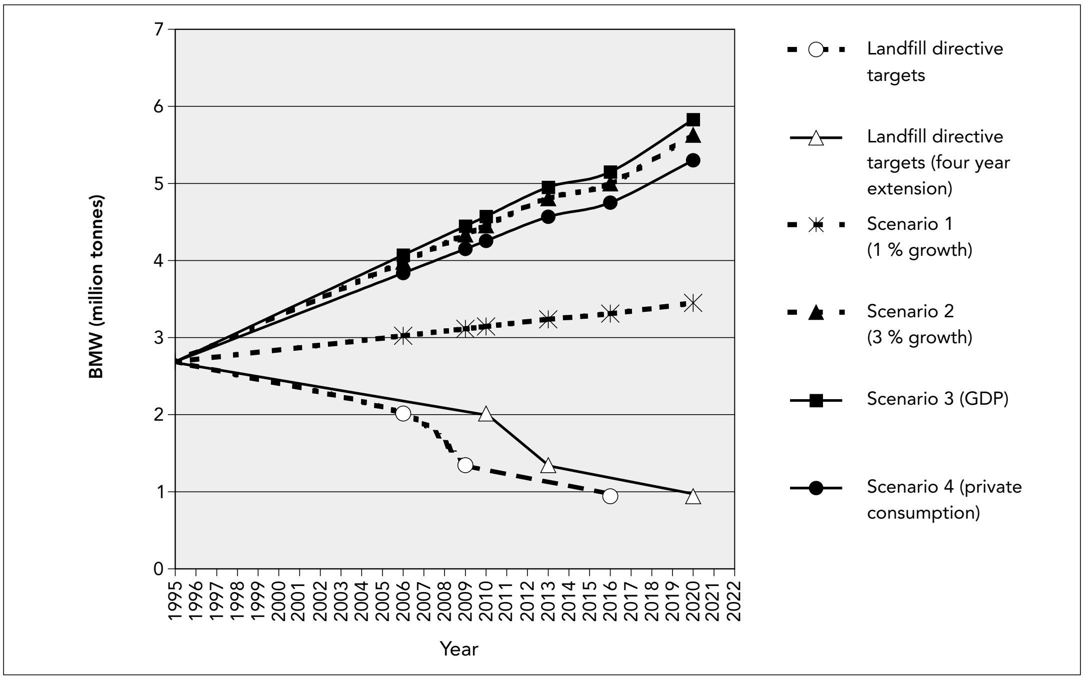
Landfill directive targets and capacity requirements A2.26

Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	28.7[1]		
1998			
GDP 2006	36.750	21.525	15.225
2009	39.310	14.350	24.96
2016	46.006	10.045	35.961
Private consumption 2006	36.062	21.525	14.537
2009	38.379	14.350	24.026
2016	44.381	10.045	34.336

1 **Source:** Eurostat

Capacity requirements based on GDP and private consumption

A2.27 **Future projections for BMW production in Greece**



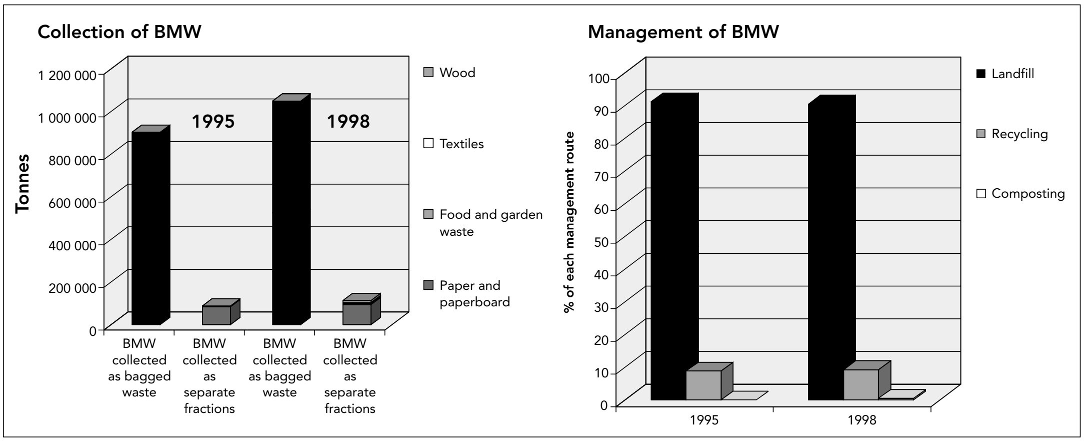
A2.28 **Landfill directive targets and capacity requirements**

Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	2.688[1]		
1997	2.613		
GDP 2006	3.779	2.016	1.763
2009	4.147	1.344	2.803
2016	5.150	0.941	4.209
Private consumption 2006	3.625	2.016	1.609
2009	3.932	1.344	2.588
2016	4.756	0.941	3.815

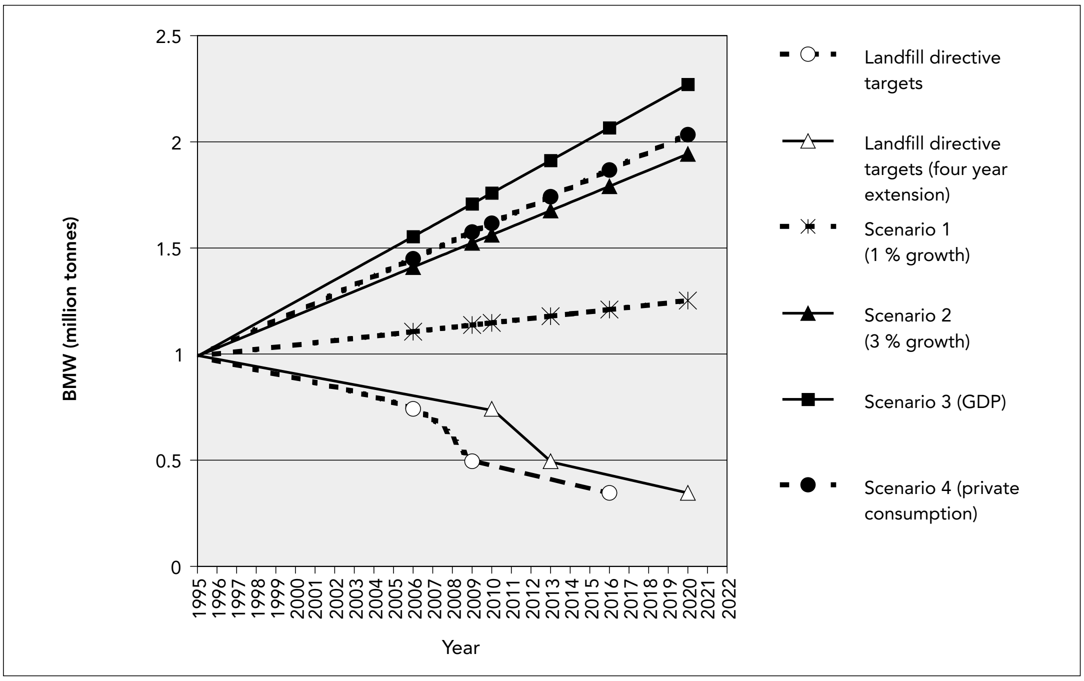
1 **Source:** Eurostat

Capacity requirements based on GDP and private consumption

Existing collection and management of BMW in Ireland — A2.29



Future projections — A2.30

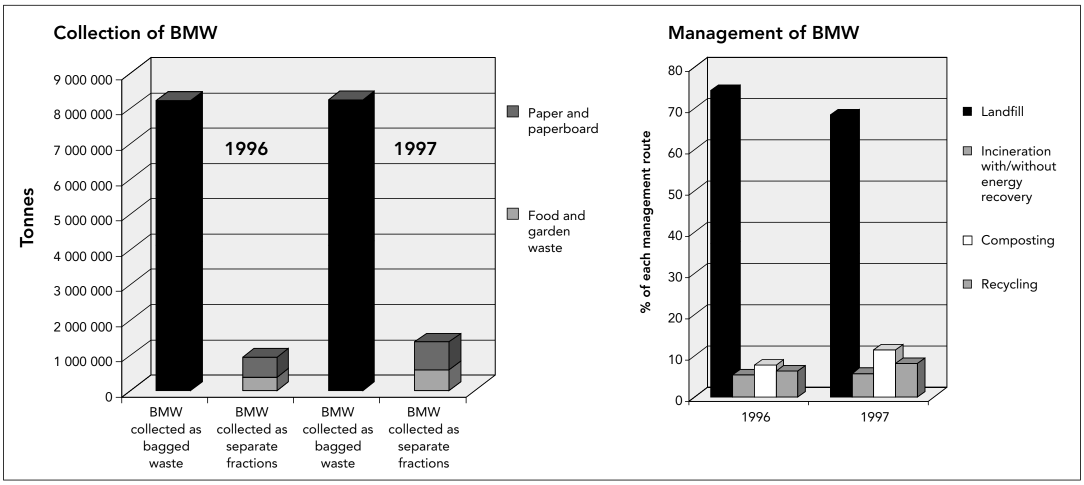


Landfill directive targets and capacity requirements — A2.31

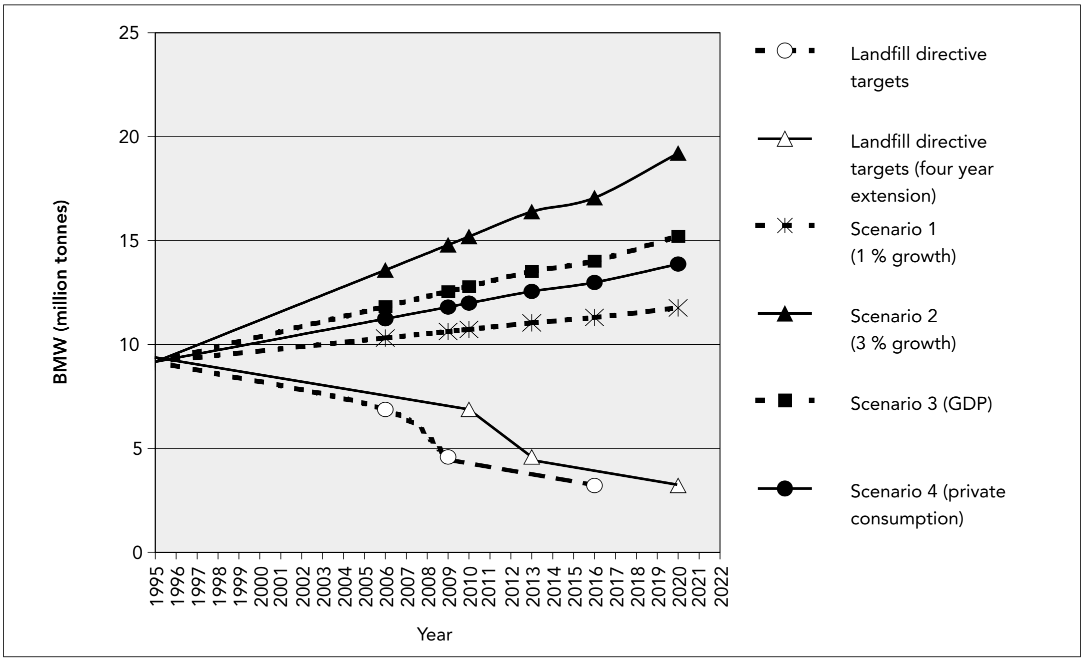
Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	0.990	0.902	0.088
1998	1.16	1.05	0.113
GDP			
2006	1.455	0.742	0.713
2009	1.617	0.495	1.122
2016	2.066	0.346	1.72
Private consumption			
2006	1.38	0.742	0.638
2009	1.51	0.495	1.015
2016	1.87	0.346	1.524

Capacity requirements based on GDP and private consumption

A2.32 **Existing collection and management of BMW in Italy**



A2.33 **Future projections**

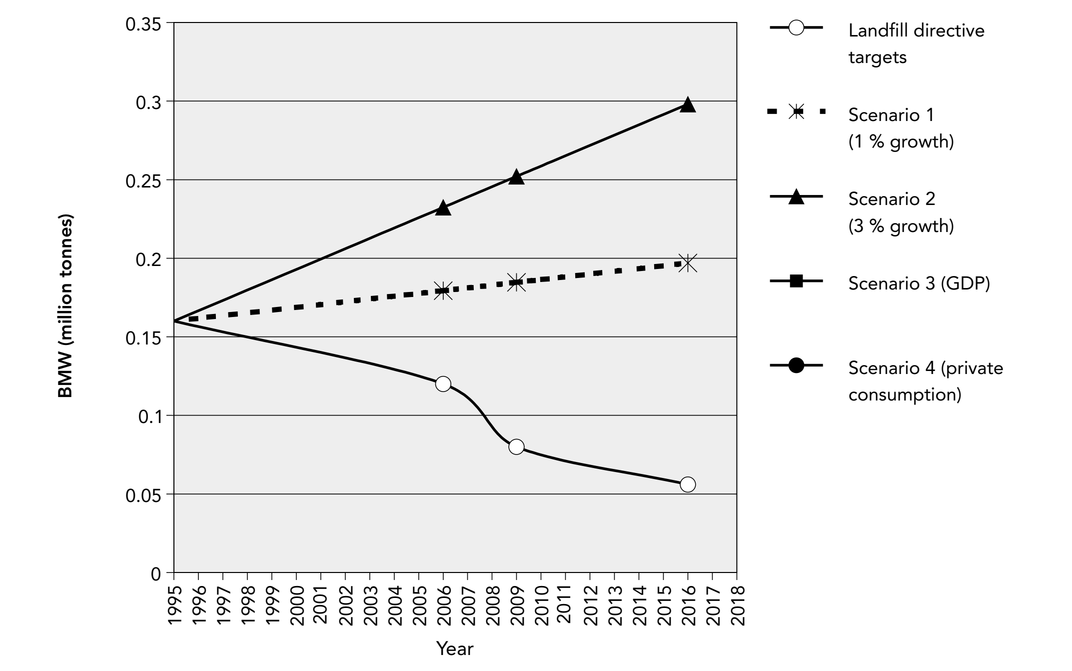


A2.34 **Landfill directive targets and capacity requirements**

Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	9.170[1]		
1998	10.092		
GDP			
2006	11.454	6.877	4.577
2009	12.170	4.585	7.585
2016	14.020	3.209	10.811
Private consumption			
2006	11.002	6.877	4.125
2009	11.563	4.585	6.978
2016	13.874	3.209	10.665

1 Figure relates to information from 1996. Latest year for information before 1995 is 1985.
Capacity requirements based on GDP and private consumption

Future projections for BMW production in Luxembourg A2.35



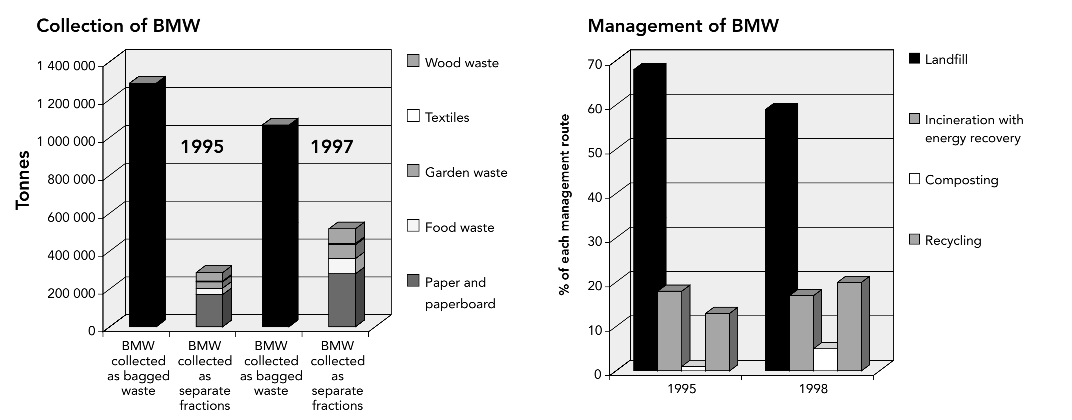
Landfill directive targets and capacity requirements A2.36

Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	0.16[1]		
1998			
GDP 2006		0.12	
2009		0.08	
2016		0.056	
Private consumption 2006		0.12	
2009		0.08	
2016		0.056	

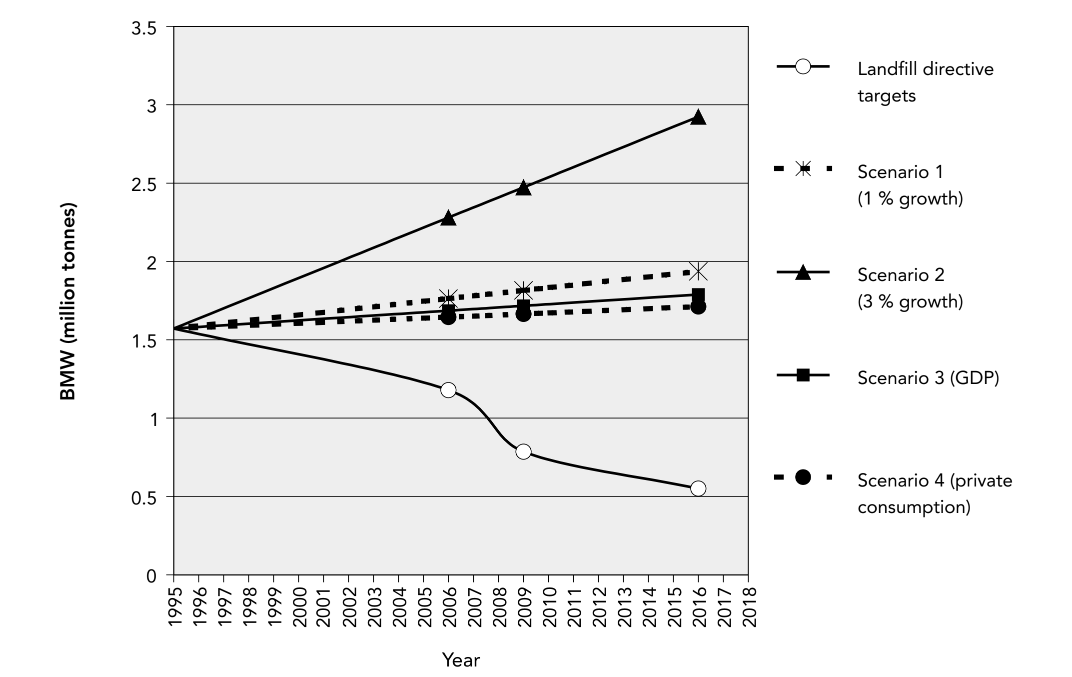
1 **Source:** Eurostat

Capacity requirements based on GDP and private consumption

A2.37	Existing collection and management of BMW in Norway



A2.38	Future projections

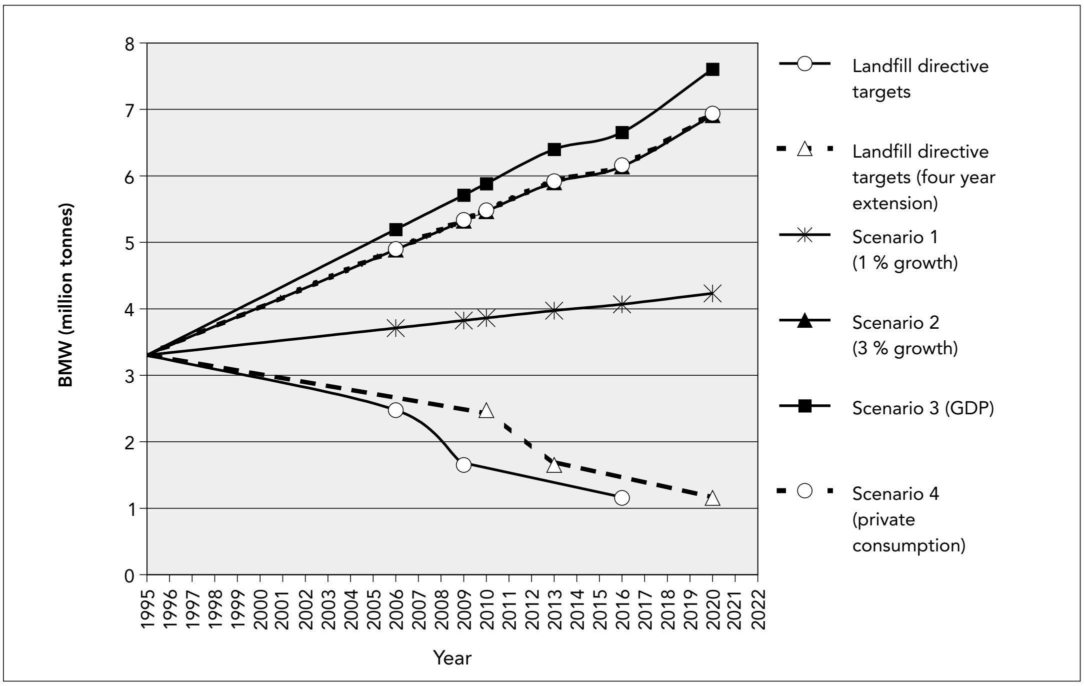


A2.39	Landfill directive targets and capacity requirements

Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	1.572		
1998			
GDP 2006	1.450	1.172	0.278
2009	1.545	0.786	0.759
2016	1.789	0.5502	1.239
Private consumption 2006	1.418	1.172	0.246
2009	1.500	0.786	0.714
2016	1.712	0.5502	1.162

Capacity requirements based on GDP and private consumption

Future projections for BMW production in Portugal A2.40



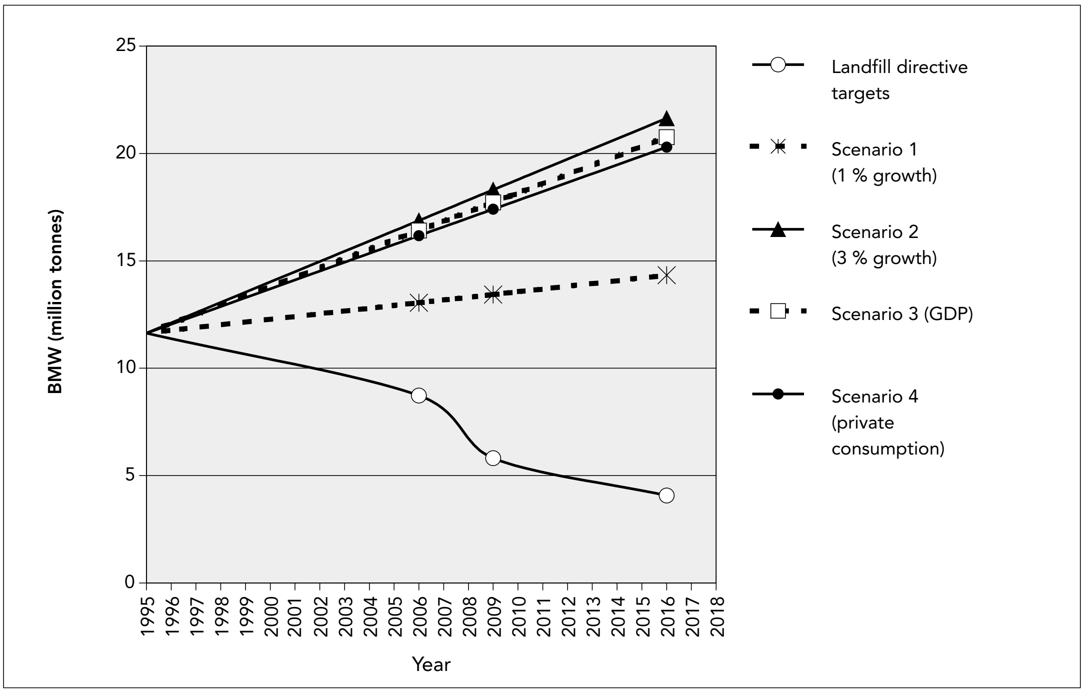
Landfill directive targets and capacity requirements A2.41

Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	3.301[1]		
1998			
GDP			
2006	4.766	2.476	2.290
2009	5.268	1.650	3.618
2016	6.655	1.155	5.500
Private consumption			
2006	4.577	2.476	2.101
2009	5.000	1.650	3.350
2016	6.160	1.155	5.005

1 **Source:** Eurostat

Capacity requirements based on GDP and private consumption

A2.42 **Future projections for BMW production in Spain**



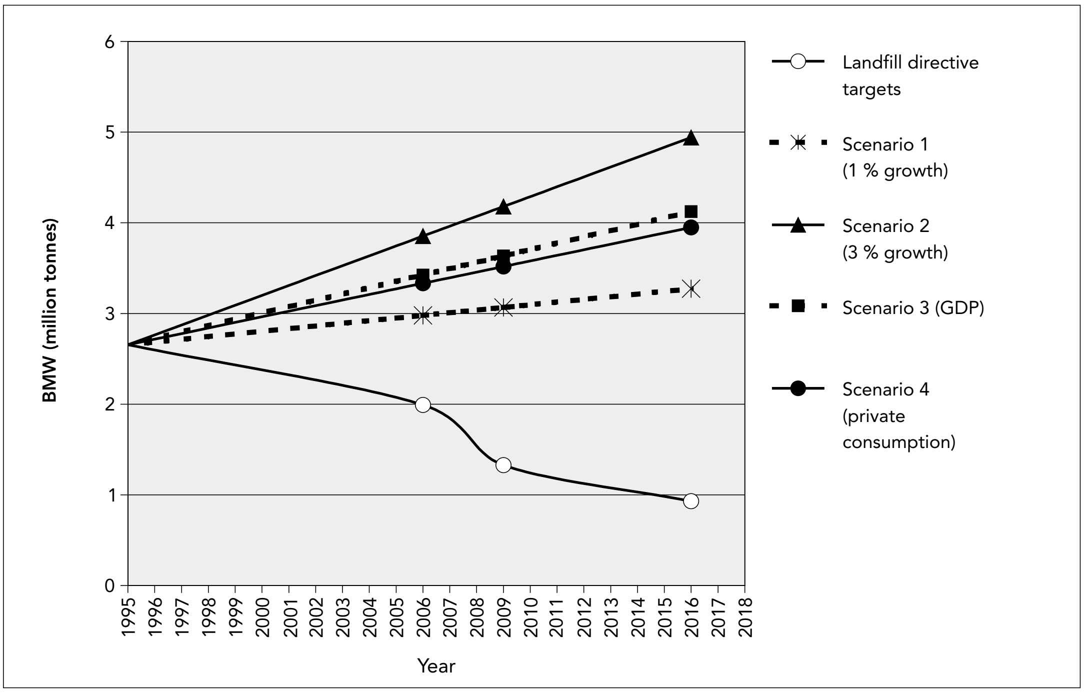
A2.43 **Landfill directive targets and capacity requirements**

Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	11.633[1]		
1998			
GDP **2006**	15.757	8.725	7.032
2009	17.117	5.816	11.301
2016	20.762	4.071	16.691
Private consumption **2006**	15.570	8.725	6.845
2009	16.857	5.816	11.041
2016	20.293	4.071	16.222

1 **Source:** Eurostat

Capacity requirements based on GDP and private consumption

Future projections for BMW production in Sweden A2.44



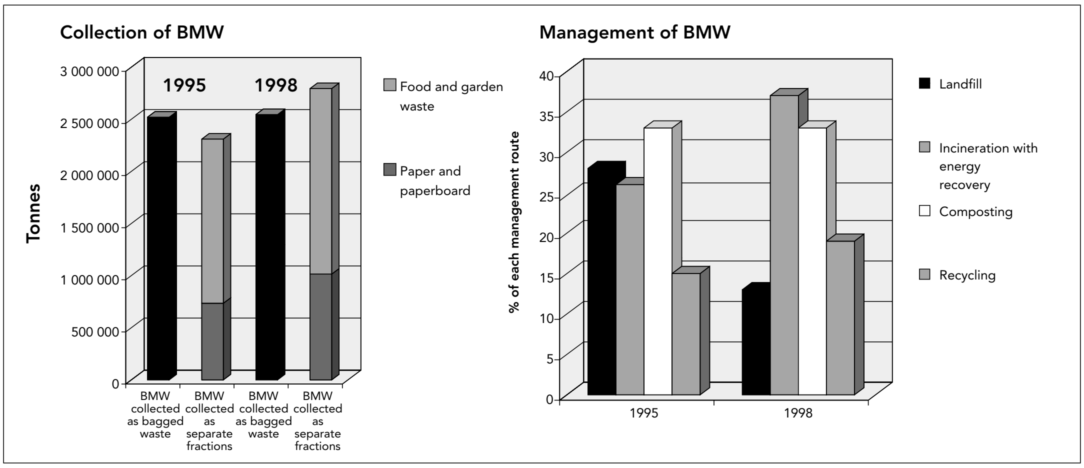
Landfill directive targets and capacity requirements A2.45

Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1994	2.656[1]		
1998			
GDP **2006**	3.344	1.992	1.352
2009	3.561	1.328	2.233
2016	4.124	0.9296	3.1944
Private consumption **2006**	3.369	1.992	1.377
2009	3.459	1.328	2.131
2016	3.948	0.9296	3.0184

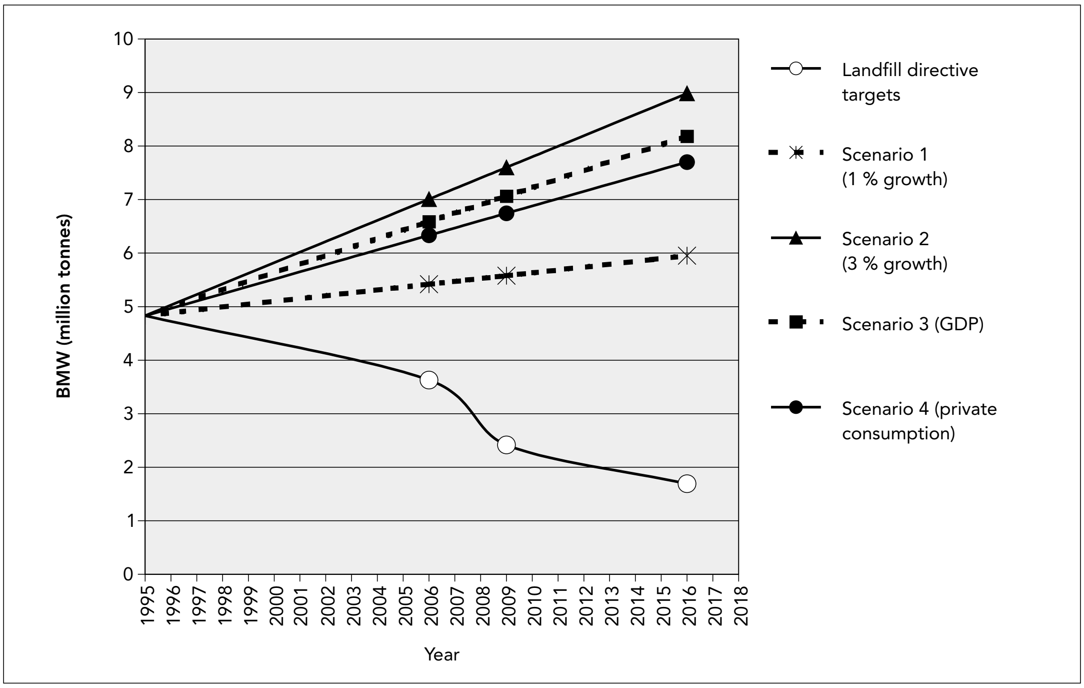
1 **Source:** Eurostat

Capacity requirements based on GDP and private consumption

A2.46	Existing collection and management of BMW in The Netherlands (1)



A2.47	Future projections



A2.48	Landfill directive targets and capacity requirements

Year	BMW produced (million tonnes)	Maximum permitted quantity of BMW to landfill (million tonnes)	Quantity of BMW to be diverted (million tonnes)
1995	4.830		
1998	5.340		
GDP			
2006	6.366	3.623	2.743
2009	6.864	2.415	4.449
2016	8.813	1.691	7.122
Private consumption			
2006	6.166	3.623	2.543
2009	6.591	2.415	4.176
2016	7.699	1.691	6.008

Capacity requirements based on GDP and private consumption

(1) All figures relate to biodegradable waste from households

Topic report 15/2001

Biodegradable municipal waste management in Europe

Part 3: Technology and market issues

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January 2002

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A great deal of additional information on the European Union is available on the Internet.
It can be accessed through the Europa server (http://europa.eu.int)

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1. Alternative technologies to landfill for the treatment of biodegradable municipal waste (BMW)

1.1. Introduction

This chapter presents an overview of the principal technologies available for diverting biodegradable municipal waste (BMW) from landfill. The focus in this report is on the food and garden waste. For each technology, the following aspects are addressed:

- brief description of the technology or technology type
- advantages and disadvantages
- typical costs
- suitability for treating BMW.

The final selection of applicable treatment methods to divert biodegradable waste away from landfills would normally depend on infrastructural, economic and environmental conditions in a particular planning area. Such an evaluation would quickly reduce the number of treatment methods relevant to the particular plan area.

Issues to be addressed in selecting treatment options include:

- quantity, type and accessibility of biodegradable material;
- proven demands for fertilisers, soil conditioners and/or energy (electricity or district heating);
- characteristics of the particular plan area (e.g. distance to farming land, construction activities including landscaping);
- availability of district heating distribution system;
- current energy price level which, based on waste fuels, will make energy production feasible;
- available sites for the establishment of treatment facilities including adequate sanitary zones.

1.1.1. Overview of treatment methods
BMW can be recycled or recovered in order to reuse cellulose fibre or to recover nutrients and energy contained in the waste. Recovery may be conducted according to two overall principles, which are biological and thermal treatment respectively.

By biological treatment methods is meant the aerobe process defined as composting and the anaerobic digestion process.

The **composting process** is feasible as a stabilising and bulk reduction method provided that a market for production of compost is established. Purification of the waste fraction by source separation is very important.

The **anaerobic digestion** method — in terms of co-digestion, wet method — is feasible as a bulk waste reduction method provided farm slurry in sufficient quantity can be supplied and local farmers use the resulting fertiliser residue. A market for gas must be established. Purification of the waste fraction by source separation is very important. The separate digestion method is technically feasible provided a market for gas and fertiliser is established. It should, however, be noted that the track record for this method is less than 10 years.

In general, biological treatment plants should be located at a suitable distance from residential areas taking into account national requirements regarding odour and noise emissions. Home-composting is suitable for suburban or dense housing areas. The composting unit should, ideally, be located more than five meters from doors and windows.

'Thermal treatment methods' in this report means incineration, gasification and pyrolysis.

Incineration ([1]) is feasible as a basic bulk reduction method. If there is energy production a market for surplus heat and/or electricity has to be established. Purification of the waste fraction is not important. Solid residuals must be reused or disposed.

Gasification and pyrolysis are emerging methods as bulk waste reduction methods but only few track records of full-scale operations at large capacities have yet been proved (e.g. the German pyrolyse plant at Burgau has been in operation since 1984).

Though environmental data from waste treatment has continuously improved in recent years, the different purposes for the technologies and the strategies on the waste have led to different data being measured using different methods. The measuring methods limit the range of data available, as some figures are hard to obtain due to technical obstacles. This can make a comparative and schematic presentation difficult.

Regional conditions will greatly influence which methods are to be chosen for the treatment of biodegradable waste in a specific area. The market for products such as compost, distribution of heat and energy, transport distances of waste, the possibility of separate collection and many other issues are central to waste planning. Consequently, Table 1 is developed to give waste planners an overview of the state of technology.

Table 1 **Overview of technologies for the treatment of BMW**

Overview of technologies for biodegradable waste	Biological method		Thermal method		
	Compost	Anaerobic digestion	Incineration	Pyrolysis	Gasification
Proven technology, track record	Yes; Very common	Yes; common	Yes; very common	Partly; few	Partly; few
Basic principle	Degradation by aerobic micro-organisms	Degradation by anaerobic micro-organisms	Combustion	Anaerobic thermo-chemical conversion	Thermo- chemical conversion
Cost of treatment	Low to high	Medium to high	Medium to high	Medium to high	High to very high
Suitability	Good	Good	Good	Medium	Depending on technology
Waste acceptance	Source separated waste only since matter and nutrients is to be recovered as pure as possible	Source separated wet waste only since matter and nutrients is to be recovered as pure as possible	All waste since air cleaning technology is good and residual solids are minimised by volume reduction	In particular suitable for contaminated, well defined dry waste fractions	Source separated dry waste only unless combined with better cleaning technology
Acceptance of wet household Waste	Yes	Yes	Yes	Possible but normally no	Possible but normally no
Acceptance of dry household Waste	Yes	Yes	Yes	Yes	Possible
Acceptance of garden and park waste	Yes	No	Yes	Yes	Possible
Acceptance of waste from hotels and restaurants	Yes	Yes	Yes	Yes	Possible but normally no
Acceptance of paper and board	Small amounts of paper possible	No	Yes	Yes	Possible
Excluded waste fractions	Metal, plastic, glass, (plants without high degree of sanitary treatment: no waste of animal origin)	Metal, plastic glass, garden waste, (plants without high degree of sanitary treatment: no waste of animal origin)	None	Wet household waste	Wet household waste
Availability of environmental data					
Solids	High	Medium — high	Medium — high	Medium	Medium

(1) See also 'economic valuation of environmental externalities from landfill disposal and incineration of waste', European Commission 2000.

Overview of technologies for the treatment of BMW, cont. Table 1

Overview of technologies for biodegradable waste	Biological method		Thermal method		
	Compost	**Anaerobic digestion**	**Incineration**	**Pyrolysis**	**Gasification**
Air	Low	Medium	Medium — high	Medium	Medium
Water	Medium — high	High	High	Medium — high	Medium — high
Control of odour	Bad — good	Bad — good	good	Medium — good	Good
Working environment	Bad — good	Medium — good	good	Good	Good
Energy recovery	No	Yes; 3 200 MJ/ tonne waste	Yes; 2 700 MJ/tonnes waste	Yes; approx. 70 % of incineration + energ y contained in the by-product char	Yes; as incineration
Carbon cycle (% of weight)	50 % in compost 50 % to air	75 % in fibres/ liquids 25 % as biogas	1 % in solids 99 % to air	20–30 % in solids 70–80 % to air	2 % in solids 98 % to air
Nutrient recovery (kg nutrient/tonne waste input)	Yes; 2.5–10 kg N 0.5–1 kg P 1–2 kg K	Yes; 4.0–4.5 kg N 0.5–1 kg P 2.5–3 kg K	No	No	No
Products for recycling or recovery, (weight- % of waste input)	40-50 % compost	30 % fibres, 50–65 % fluids	15–25 % bottom ash (incl. clinker grit, glass), 3 % metal	30–50 % char (incl. bottom ash, clinker, grit, glass), 3 % metal	15–25 % vitrified bottom ash (incl. clinker grit, glass). 3 % metal
Residuals for other waste treatment or for land filling (weight- % of waste input)	2–20 % overflow sieving (plastic, metal, glass, stones)	2–20 % overflow sieving (plastic, metal, glass, stones)	3 % fly ash (incl. flue gas residues)	2–3 % flue gas residues	2 % gas cleaning residues

1.2. Centralised composting

1.2.1. Brief description of technology

Biodegradable waste is composted with the objective of returning the waste to the plant production cycle as fertiliser and soil improver. The variety of composting technologies is extensive as composting can be carried out in private gardens as well as in advanced, highly technological centralised plants. The control of compost processing is based on the homogenisation and mixing of the waste followed by aeration and often irrigation. This leads to a stabilised dark media, rich in humic substances and nutrients. Central solutions are exemplified by low cost composting without forced aeration and technologically more advanced systems with forced aeration and temperature feedback. Central composting plants are capable of handling more than 100 000 tonnes of biodegradable waste per year, but typically the plant size is about 10 000 to 30 000 tonnes per year. Biodegradable wastes must be separated prior to composting: only pure food waste, garden waste, wood chips and, to some extent paper, are suitable for producing good quality compost.

The composting plants consist of some or all of the following technical units: bag openers, magnetic and/or ballistic separators, screeners (sieves), shredders, mixing and homogenisation equipment, turning equipment, irrigation systems, aeration systems, draining systems, bio-filters, scrubbers, control- and steering systems.

The composting process occurs when biodegradable waste is piled together with a structure allowing oxygen-diffusion and with a dry matter content suiting microbial growth. The temperature of the biomass increases due to the microbial activity and the insulation properties of the piled material. The temperature often reaches 65–75°C within a few days and then declines slowly. This high temperature furthers the elimination of pathogens and weed seeds.

Depending upon the composition of the waste material and the applied method of composting, the compost will be ready after three to 18 months. The products of central composting are solids in the form of compost and residuals; fluids in the form of leachate; gas in the form of carbon dioxide, evaporating water and ammonia. Odorous compounds other than ammonia may be generated especially when oxygen supply is inadequate.

The stabilised compost is screened before being used for plant growing purposes. The screen overflow (residuals) is recycled as structural material for the composting process or land filled if the content of visible impurities is high. The leachate is used for watering the composting mass or is discharged. Composting systems operating with an exhaust air system may heat-exchange the incoming air, while ammonia etc. can be treated in scrubbers and bio-filters.

In general, composting methods can be divided into two main groups: composting *without* forced aeration and *with* forced aeration. A lot of confusion exists regarding naming of the different compost treatment options. The following terminology is recommended. Composting with forced aeration is subdivided into batch-wise/static composting or continuously/agitated composting in relation to the principles of feeding and turning regimes (Stentiford, 1993; Finstein and Hogan, 1993). Static piles are turned only weekly or monthly, whereas agitated piles are moved continuously giving room for continuous feeding. If all materials are set up at the same time its called batch-wise. See Table 2.

Table 2 **Categorisation of composting method**

Method	Principles for feeding and turning	Demands on structure-stability *	Type of facility
Without forced aeration	Batch-wise and static	Very high High	Mattress/bed (1) Windrow (1)
With forced aeration	Batch-wise and static	High High High	Aerated-windrow (2) Semi-permeable cover (3) Container/box/tunnel-static (4)
	Continuously and agitated	Medium Medium Medium Medium Low	Indoor-mattress/agitated-bed (4) Channel/agitated-bay (4) Tunnel-agitated (4) Tower multi-floor (4) Drum (4)

*): on final mixture of input material.

Footnotes 1-4: Indicates increasing degree of odour control possibilities (often of costs as well). Odour problems often stem from pre-treatment. Footnotes 3 and 4 are in-vessel type of facilities.
Reference: UK Compost Association, 1999; Stentiford, 1993; Finstein and Hogan, 1993).

1.2.2. Advantages and disadvantages

Advantages

- Possible simple, durable and cheap technology (except some in-vessel facilities);
- approximately 40–50 % of mass (weight) is recovered for plant growth;
- maximum recovery of the nutrients required for low-input farming systems (i.e., P, K, Mg and micronutrients). Liming effect of compost;
- production of humic substances, beneficial micro-organisms, and slow-release nitrogen required for landscape gardening and horticulture;
- eliminates weeds and pathogens in the waste material;
- possible good opportunities of process control (except at most facilities without forced aeration);
- good working environment can be achieved (e.g. pressurised operating cabins with filters).

Disadvantages

- Requires source separation of BMW, including continuous information to waste generators;
- a market for the compost products must be developed and maintained;
- periodical emission of odorous compounds, especially when treating BMW;
- loss of 20–40 % of nitrogen as ammonia, loss of 40–60 % of carbon as carbon dioxide;
- potential vector-problems (seagulls, rats, flies) when treating BMW;
- skilled staff needed when treating BMW.

1.2.3. Typical costs

Composting without forced aeration

Plants typically consist of a few buildings, mobile machinery, and the composting area covered by a roof or uncovered, and with some kind of pavement. Usually it is cheaper to build a plant for pure garden waste. This is not taken into account in Table 3.

Composting without forced aeration Table 3

Economic information		
Capacity (tonnes per annum)	**Typical capital costs Note 1 (EUR)**	**Typical operating costs Note 2 (EUR)**
2 000	300 000	130 000
5 000	600 000	240 000
10 000	900 000	400 000
20 000	1 300 000	730 000
50 000	2 200 000	1 3500 000
100 000	4 500 000	2 600 000

Note 1: Capital costs including site costs, planning costs and construction/plant development costs.
Note 2: Operating costs excluding the costs of residue disposal, staff costs, income from sales of residue/by products.
Reference: Morten Brøgger, pers. comm.

Composting with forced aeration

Capital costs obviously vary depending on the chosen type of facility. This in turn is dependent on the demands for air cleaning, water treatment, waste fractions etc. Operating costs have been calculated from knowledge gained from existing plants. It is very difficult to compare operating costs, as these depend heavily on account principles and local conditions. The figures in Table 4 are reliable for general planning purposes.

Composting with forced aeration Table 4

Economic information		
Capacity (tonnes per annum)	**Typical capital costs Note 1 (EUR)**	**Typical operating costs Note 2 (EUR)**
2 000	550 000–800 000	270 000
5 000	950 000–1 500 000	550 000
10 000	1 600 000–2 700 000	950 000
20 000	2 700 000–4 700 000	1 600 000
50 000	5 400 000–9 400 000	2 700 000
100 000	9 400 000–16 100 000	5 400 000

Note 1: Capital costs including site costs, planning costs and construction/plant development costs.
Note 2: Operating costs excluding the costs of residue disposal, staff costs, income from sales of residue/by-products.
Reference: Wannholt, 1999b; UK Compost Association, 1999; Morten Brøgger, pers. comm.

1.2.4. Suitability for diverting BMW away from landfill

Composting is highly suitable as an option for diverting BMW away from landfill. The principal advantages are that a useful and potentially valuable product is being manufactured from waste and that the negative consequences associated with land filling such as the production of landfill gas and leachate with high BOD are avoided.

The main obstacle to successful composting of BMW is contamination of the waste stream. There is little point in investing public or private money in the construction of composting facilities if, at the end of the day, the compost produced cannot be put to beneficial use due to inadequate quality. A key strategic issue, therefore, is ensuring that as 'clean' as possible a waste stream is collected for composting. This means investing resources in separate collection and public education.

Another key issue is ensuring that adequate and reliable markets are available for compost produced from BMW.

1.3. Home and community composting

An overview of different types of home and community composting facilities is presented in Table 5. Simple home composting technology is normally not suitable for treating BMW of animal origin, because operating temperatures rarely exceed 55 °C and, through inadequate mixing, not all the waste material is exposed to a suitably high temperature. Where an (isolated or placed inside) automatic turning drum with a batch feeding system is used or similar batch systems, BMW of animal origin as well as of vegetable origin can, generally, be composted without any particular health risks. However, care and caution are required when composting wastes of animal origin to ensure that the waste is adequately treated and does not pose a health risk. This would include ongoing monitoring of both the process and the compost produced.

The composting process in home composting facilities treating BMW must be furthered by the addition of fairly dry, carbonaceous structural material to lower the loss of nitrogen during the composting and to lower the risk for anaerobic conditions. The need for a proper amount of carbonaceous material is often not fulfilled. The municipality could provide a shredding service to the home composters shredding their woody garden waste a few times yearly and possible supplement with extra wood chips if needed.

Local, environmentally sound home composting schemes in city blocks and dense low suburban housing depend on the availability of sufficiently large green spaces such as garden lots, shrubbery, lawns etc. on which to use the compost. A minimum of 1 m^2 green area per 10 % of the 'BMW potential per participating person' being home composted, is needed to avoid over-fertilisation with N and P (2). Typically, 50 % of the 'municipal biodegradable waste potential' will be collected and composted, and the area needed is then 5 m^2 per participating person (Reeh, 1996; U. Reeh, pers. comm.). However, phosphorous must be also removed from the area (i.e. by harvesting crops) to avoid over-fertilisation.Participation of 60-80 % of all households in a home composting scheme is common, though some of these households do not actively use their composting container (Domela, 2000; Skaarer & Vidnes, 1995; Reeh, 1992).

Garden waste from private gardens or parks may be shredded on-site and used for mulching of the grounds below bushes etc. as a way to prevent the establishment of annual weeds. This effect lasts 1–2 years for shredded mixed garden waste (no or low content of green leaves) and longer for shredded branches. It must be noted, that plant pathogens can easily be spread with the chips if any of the plant material is infected. Infected plant material should be taken to incineration. Especially when shredding garden waste for private garden owners, the resulting chips should be used in the same garden. Landscape gardeners working with the maintenance of parks will normally be able to recognise infected plant material and remove it. There are a large number of shredders and smaller chippers on the market.

1.3.1. Suitability for diverting BMW away from landfill

Home or community composting is suitable for treating BMW and can contribute to a reduction in the quantities of BMW put out for collection. A key advantage of community composting is that it is a local solution to a waste management problem and directly involves the community in dealing with its own waste. Generally, individuals or communities that engage in home or community composting are likely to have a higher awareness about waste issues which should have a knock-on effect on the reuse or recovery of other waste streams.

However, it is unlikely that home and community composting alone will deliver the levels of BMW diversion from landfill required to meet the targets set by the landfill directive and it would therefore be unwise to rely solely on small-scale composting initiatives to deliver the diversion rates required by the directive. Ideally, a mixture of central composting, particularly

(2) This calculation is based upon the collection of 43 kg BMW of vegetable origin per participant per year, 70 % of the households participating and a resulting compost containing 1.4 % N-total and 0.3 % P-total in the dry matter.

for large urban and suburban areas and community/home composting for small urban and rural areas should be encouraged, to maximise participation in composting schemes.

Overview of four types of home and community composting facilities Table 5

	Simple pile	Small container	Medium sized containers or composting area	Automatically rotating insulated drum
Acceptable waste	BMW of vegetable origin only. Garden waste without branches. Chopped garden waste.	BMW of vegetable origin only. Soft green garden waste. Small amount of chopped garden waste.	BMW of vegetable origin only. Soft green garden waste. Small amount of chopped garden waste.	BMW of vegetable and animal origin. Soft green garden waste. Small amounts of chopped garden waste.
No of households	1	1–4	50–250	40–120
Price of installation (EUR)	0	50-500	3 000–25 000 *	14 000–25 000 *
Estimated work (hr./month/ installation)	0–2	1–4	5–25	5–10
Needed level for information and control	Low	Low	High (avoiding visible impurities)	High (avoiding visible impurities)
Composting time (months)	12–36	9–18	2–9	2–9
Use of compost worms	Possible Unusual	Possible Common	Often possible Unusual	Not possible
Quality of product	Low (weeds, plant pathogens)	Low-medium (weeds, plant pathogens)	Low-medium (weeds, plant pathogens)	Low-high

Examples:
Small container: Example of a static plastic drum 'Humus' (1–2 households, EUR 75 /installation). Example of a static, insulated double box 'Rotate 550' (1-2 households, EUR 160 /installation; Swedish manufactured). Examples of a manually rotated, insulated drum 'CorroKomp 230' and 'Joraform JK 270' (2-4 households, EUR 500 /installation; Swedish manufactured).
Composting area: Example 'Nonneparken' in Herfølge, Denmark (155 households, EUR 21 000 for installation, 10 hr/month; from Reeh, 1992).
Automatically rotating insulated drum: Example 'CorroKomp 2000' (40–60 households, EUR 14 000 /installation with two drums; Swedish manufactured) and 'Joraform JK 2700' (60–120 households, EUR 21 500 /installation with two drums; Swedish manufactured).
* The more expensive solutions are normally chosen for a lower number of selected (low-density) residential areas and are not seen as the solutions for an entire town.
References: Knud Rose Petersen, pers. comm.; Karin Persson, pers. comm., Ulrik Reeh, pers. comm.

1.4. Anaerobic digestion

1.4.1. Brief description of technology

Anaerobic digestion is a biological treatment method that can be used to recover both nutrients and energy contained in biodegradable municipal waste. In addition, the solid residues generated during the process are stabilised. The process generates gases with a high content of methane (55–70 %), a liquid fraction with a high nutrient content (not in all cases) and a fibre fraction.

Waste can be separated into liquid and fibre fractions prior to digestion, with the liquid fraction directed to an anaerobic filter with shorter retention time than that required for treating raw waste. Separation can also be conducted following digestion of the raw waste so that the fibre fraction can be recovered for use, for example as a soil conditioner. The fibre fraction tends to be small in volume but rich in phosphorus, which is a valuable and scarce resource at global level.

Anaerobic digestion technologies chosen for treating BMW have generally consisted of separate digestion in a 'dry' process (e.g. Valorga, Kompogas, Dranco) because most of the plants digesting household waste tend to be established in large cities where implementation of integrated solutions (i.e. co-digestion with other waste products) is difficult due to relative unavailability of liquid manure.

The three main methods available, separate digestion (dry method), separate digestion (wet method) and co-digestion (wet method) are described below.

Separate digestion, dry method
With separate digestion, dry method, the organic waste is first tipped into a shredder to reduce the particle size. The waste is sieved and mixed with water before entering the digester tanks (35 % dry matter content). The digestion process is carried out at temperatures of 25–55 °C resulting in the production of biogas and a biomass. The gas is purified and used in a gas engine. The biomass is de-watered and hereby separated into 40 % water and 60 % fibre and reject (having 60 % dry matter). The reject fraction which is disposed at, for example, a landfill. The wastewater produced is recycled to the mixing tank ahead of the digester.

Separate digestion, wet method
With separate digestion, wet method, the organic waste is tipped into a tank, where it is transformed into a pulp (12 % dry matter). The pulp is first exposed to a hygienic process (70 °C, pH 10) before being de-watered. The de-watered pulp is then hydrolysed at 40 °C before being de-watered once again.

The liquid from the second de-watering step is directed to a bio-filter where the digestion is carried out resulting in biogas and wastewater. This water is reused in the pulp or, for example, may be used as a liquid fertiliser. The fibre fraction from the second de-watering is separated into compost and reject fractions to be disposed of at, for instance, landfill. The compost usually requires further processing prior to sale. The biogas is purified and utilised in a gas engine resulting in the production of electricity, heat and flue gas. Some of the heat can be used to ensure stable temperatures during the hydrolysis and the bio-filter processes.

In this process, one tonne of household waste will generate 160 kg biogas (150 Nm^3), 340 kg liquid, 300 kg compost fraction and 200 kg residuals (including 100 kg inert waste). According to analyses it is found that 10–30 % of the nutrient content (tot-N, tot-P and tot-K) remains in the compost fraction.

Co-digestion, wet method
With co-digestion, wet method, organic waste is shredded and screened before further treatment. The shredded waste is then mixed with either sewage sludge or manure from farms, at a ratio of 1:3–4. The mixed biomass is first exposed to a hygienic process (70°C) before being fed to the digestion phase, which is conducted at temperatures of 35-55 °C. The process generates biogas and a liquid biomass, which is stored before being used as a liquid soil fertiliser. The biogas is purified and utilised in a gas engine resulting in the production of electricity, heat and flue gas. Some of the heat can be used to ensure stable temperatures during the hygienic and the digestion phases.

One tonne of household waste will generate 160 kg biogas (150 Nm^3), 640 kg liquid fertiliser, 0 kg compost fraction and 200 kg residuals (including 100 kg inert waste). According to analyses it is found that 70–90 % of the nutrient content (tot-N, tot-P and tot-K) remains in the liquid fertiliser fraction. Thus it is possible to achieve very high recovery and utilisation of the nutrients. However it should be emphasised that liquid fertilisers, produced from sewage sludge, are much more difficult to sell than liquid fertilisers produced from manure.

1.4.2. Advantages and disadvantages
The mentioned advantages and disadvantages are accountable for all three anaerobic treatment methods.

Advantages
- Almost 100 % recovery of nutrients from the organic matter (nitrogen, phosphorus and potassium) if the digested material is ploughed down immediately after spreading on the fields

- production of a hygienic fertiliser product, without risk of spreading plant and animal diseases. The nitrogen is more accessible for the plants after digestion
- reduction of odour, when spreading on the fields compared with spreading of non-digested material
- CO_2 neutral energy production in the form of electricity and heat
- substitution of commercial fertiliser.

Disadvantages

- Requirements for source separation of waste
- the fibres require additional composting if intended for use in horticulture or gardening
- a market for the liquid fertiliser must be developed before establishment of the treatment method, unless the liquid has a very low nutrient content and thereby can be discharged to the public sewer
- methane emissions from the plant and non-combusted methane in the flue gasses (1–4 %) will contribute negatively to the global warming index.

1.4.3. Typical costs

Separate digestion, dry method Table 6a

Economic information		
Capacity Note 1 (tonnes per annum)	**Typical capital costs Note 2 (EUR)**	**Typical operating costs Note 3 (EUR)**
5 000	2.9–3.1 million	120 000 p.a.
10 000	5.3–5.6 million	220 000 p.a.
20 000	9.5–10.0 million	400 000 p.a.

Note 1: The BMW proportion amounts to approximately 100 % of the annual input.
Note 2: Plant cost excluding energy conversion gas engine, tax, planning and design fee. (Hjellnes Cowi AS and Cowi AS, 1993).
Note 3: Operating costs excluding the costs of transport, residue disposal, staff costs, income from sales of residue/by products and incomes from net sales of energy. Operating costs includes yearly maintenance costs estimated to 4 % of the initial capital cost. (Hjellnes Cowi AS and Cowi AS, 1997).

Co-digestion, wet method Table 6b

Economic information		
Capacity Note 1 (tonnes per annum)	**Typical capital costs Note 2 (EUR)**	**Typical operating costs Note 3 (EUR)**
20 000	3.7–4.5 million	130 000 p.a.
50 000	4.6–5.5 million	150 000 p.a.
100 000	10.5–12.5 million	350 000 p.a.

Note 1: The BMW proportion amounts to approx. 20 % of the annual input.

Note 2: Plant cost excluding energy conversion gas engine, tax, planning and design fee. (Danish Energy Agency, 1995).

Note 3: Operating costs excluding the costs of transport, residue disposal, staff costs, income from sales of residue/by products and incomes from net sales of energy. Operating costs includes yearly maintenance costs estimated to 3 % of the initial capital cost. (Danish Energy Agency, 1995; Claus D. Thomsen, pers. comm., Reto M. Hummelshøj, pers. comm.).

Staff costs may vary from plant to plant i.e. 5–15 persons for 100 000 tonnes per annum per plant. Total operating costs excluding transport may reach EUR 6 per tonne (Linboe et al., 1995). Electric consumption at a plant is typically about 0.2 kWh/m^3 biogas, and process heat consumption about 3 MJ/m^3 biogas.

1.4.4. Suitability for diverting BMW away from landfill

Anaerobic digestion is fully suitable for treatment of the food fraction of BMW presuming that the waste is pre-sorted. Anaerobic digestion is not suitable for treating newspaper, textile and wooden park waste. Anaerobic digestion produces biogas that can be used for heating or combined heat and power production, provided that there is a market — or the gas can be used to power public transport vehicles such as town buses or waste collecting lorries. The liquid fertiliser, slurry or fibre fraction from anaerobic digestion is optimally used in cooperation with agriculture.

1.5. Incineration

1.5.1. Brief description of technology

Incineration reduces the amount of organic waste in municipal waste to about 5 % of its original volume and sterilises the hazardous components, while at the same time generating thermal energy that can be recovered as heat (hot water/steam) or electric power or combinations of these. The incineration process also results in residual products, as well as products from cleaning of the flue gas, which have to be deposited at a controlled disposal site such as a landfill or a mine. Sometimes wastewater is produced. Nutrients and organic matter are not recovered. The principal technologies available on the market are described below.

Grate incineration

Waste is tipped into a silo, where a crane mixes the incoming material. Often bulky material is shredded and returned to the silo. The mixed waste is then fed into the incinerator's charging chute by means of the crane system. From the charging chute, the waste is fed into the furnace. It is dried and ignited on the first grate parts, by the time it reaches the latter grate parts it is burnt out and leaves the furnace in the form of clinker. The incineration temperature is at a minimum of 950 °C and the retention time in the after-burner should be a minimum of 2 seconds at a minimum of 850 °C.

At larger incinerators, the grate system is supplemented with a rotary kiln ensuring efficient burnout of all combustibles. The hot flue gases produced during the incineration process are led to a boiler plant specifically designed for flue gases from incineration of waste. In this boiler the energy is utilised for steam or hot water production.

Fluidised bed incineration

A few fluidised-bed incinerators are in operation in Europe. The main difference between the fluidised bed technology and the grate systems is that the grate is substituted with a fluidised sand bed to transport the waste during the incineration process. The fluidising process is obtained by blowing air from underneath the sand bed in an upward direction. Depending on the air velocity the fluidised bed system may either be bubbling or circulating, where the airborne volatile fines are returned to the incineration zone after passage of a cyclone. Fluidisation may also be achieved by rotating beds.

Compared to the grate combustion process described above there are some major differences such as:

- the fluid bed is more sensitive to bulky waste but less sensitive to fluctuations in the calorific value;
- the fluid bed incineration process produces a low amount of NO_x, which is comparable with grate systems with flue gas re-circulation and optimised process control;
- the fluid bed process has a lower thermal flue gas loss but a higher parasitic power demand — some 50 % higher than the grate based system;
- the clinker from the fluid bed system is very inert and the amount of non-combusted material is very low in the clinker, but the fly ash production is considerably higher than at the grate systems;
- the fluid bed has been shown to involve a slightly higher capital investment.

Flue gas cleaning

Before leaving the boiler the flue gases are cleaned in a flue gas purification plant in which particles, heavy metals, acid gases like hydrochloric acid, HF, SO_2, NO_x and dioxins are removed before the flue gas, through a fan, is fed to a chimney. There are three principle systems used for the cleaning of flue gases:

- the dry system, with dry lime injection, activated carbon injection and bag-house filter;

- the semi-dry system, with injection of lime slurry, activated carbon injection and bag-house filter;
- the wet system, with an electrostatic precipitator in front of a wet, two-stage scrubber for acid gases followed by activated carbon injection and bag-house filter.

There are different ways of designing the flue gas cleaning system. These differences are usually due to the variations in national legislation within the European countries. Some countries, for example, do not allow the production of wastewater, which results in a combination of the different processes.

1.5.2. Advantages and disadvantages

Advantages

- Well-known process installed worldwide, with high availability and stable running conditions (this bullet counts for grate incineration only)
- Energy recovery with high efficiency of up to 85 % can be achieved, if generating combined heat and power or heat only
- All municipal solid waste as well as some industrial wastes can be disposed of unsorted via this process
- The volume of the waste is reduced to 5–10 %, which primarily consists of clinker that can be recycled as a gravel material for road building if sorted and washed;
- The clinker and other residues are sterile
- CO_2 neutral energy production, substituting combustion of fossil fuels.

Disadvantages

- Extensive investments
- Extensive flue gas cleaning system
- Generation of fly ash and flue gas cleaning products, which have to be deposited at a controlled landfill (amounts to approximately 2–5 % by weight of the incoming waste)
- Generation of NO_x and other gases as well as particles.

1.5.3. Typical costs

Grate incineration Table 7

Economic information		
Capacity (tonnes per annum) Note 1	**Typical capital costs Note 2 (EUR)**	**Typical operating costs Note 3 (EUR)**
50 000	25 million	950 000 p.a.
100 000	45 million	1 750 000 p.a.
200 000	90 million	4 000 000 p.a.
500 000	160 million	6 800 000 p.a.

Note 1: The BMW proportion amounts typically to 50–70 % of the annual input.

Note 2: Plant cost excluding tax, planning and design fee and land based on Danish conditions. In central Europe the cost of plants is approximately a factor 1.5–2 higher, especially in Germany. (Reto M. Hummelshøj, pers. comm., Stig Gregersen, pers. comm.).

Note 3: Operating costs excluding the costs of transport, residue disposal, staff costs, income from sales of residue/by products and incomes from net sales of energy. Operation costs includes yearly maintenance cost estimated to 3 % of the initial capital costs. (MCOS/Cowi, 1999).

A plant with extensive flue gas cleaning and combined heat and power production, in order to operate continuously, will require between 20 and 40 people, depending on plant size, but also on the number of administrative staff situated at the incineration plant and degree of outsourcing of maintenance work. A simple biomass boiler plant for wooden park waste will have a capital cost of about EUR 0.5 million per MJ/s capacity and total operating cost of EUR 25 000–40 000 p.a. per MJ/s capacity.

1.5.4. Suitability for diverting BMW away from landfill

Incineration can be considered technically and economically feasible provided the market for the energy products of heat and power is available and stable. Thermal treatment, with waste to energy (WTE), is environmentally sound with lower greenhouse gas emissions compared with landfills, anaerobic digestion and composting.

Dioxin-type compounds in emissions to the atmosphere may be a public issue when decision-makers are going to choose a waste treatment system but there are strict EU standard limits on emissions of dioxin etc. from incineration plants.

It should be noted that addition of relatively non-polluting waste, such as certain fractions of BMW, may increase the total emission doze of pollutants as the flue gas quantity is increased. The main disadvantage of incineration is the high cost and that nutrients such as phosphorus and potassium and humus, present in the raw waste, are lost.

1.6. Pyrolysis and gasification

1.6.1. Brief description of technologies

Pyrolysis and gasification represent refined thermal treatment methods as alternatives to incineration. The methods are characterised by the transformation of the waste into product gas as energy carrier for later combustion in, for example, a boiler or a gas engine. Flue gas volumes are reduced in comparison to incineration, so that the demand for voluminous flue gas cleaning equipment is reduced.

The purpose of pyrolysis and gasification of waste is to minimise emissions and to maximise the gain and quality of recyclable products as well as to minimise the amount of organic waste and sterilise the hazardous components. Surplus heat is generated and can be recovered as heat (hot water/steam) or electric power or combinations of these with a high power-to-heat ratio. The processes produce residual products, as well as products from cleaning of the gases, which has to be deposited at a controlled landfill/mine. Wastewater is also normally produced and treated before it is discharged to the sewage system or evaporated in cooling towers. Nutrients and organic matter are not recovered.

Pyrolysis

Pyrolysis is a thermal pre-treatment method, which can be applied in order to transform organic waste to a medium calorific gas, liquid and a char fraction aimed at separating or binding chemical compounds in order to reduce emissions and leaching to the environment. Pyrolysis can be a self-standing treatment, but is mostly followed by a combustion step and, in some cases, extraction of pyrolytic oil (liquefaction).

Waste is tipped into a silo where a crane mixes the incoming material and moves the material to a shredder and from here to another silo. The mixed waste is then fed into a gas tight hopper arrangement, screw- or piston feeder. The coarsely shredded waste now enters a reactor normally an external heated rotary drum operated under atmospheric pressure. In the absence of oxygen the waste is dried and hereafter transformed at 500–700 °C by thermo-chemical conversion i.e., destructive distillation, thermo-cracking and condensation into hydrocarbons (gas and oils/tar) and solid residue (char/pyrolysis coke) containing carbon, ash, glass and non-oxidised metals.

If the process temperature is 500 °C or below, the process is sometimes called thermolysis. The retention time of the waste in the reactor is typically 0.5-1 hour. The >300 °C hot product gas is normally led to a boiler plant, where the energy content is utilised for steam or hot water production. The raw product gas is **not** suitable for operation of an internal combustion engine due to the high content of tar in the gas phase, which will condense when the gas is cooled before entering the gas engine. Thermo-cracking of the tars in the gas followed by gas cleaning may solve the cleaning need.

Gasification

Gasification is a thermal treatment method, which can be applied to transform organic waste to a low calorific gas, recyclable products and residues. Gasification is normally followed by combustion of the produced gasses in a furnace and in internal combustion engines or in single gas turbines after comprehensive cleaning of the product gas. Coarsely-shredded, sometimes pyrolysed waste enters a gasifier, where the carbonaceous material reacts with a gasifying agent, which may be air, O_2, H_2O in the form of steam, or CO_2. The process takes place typically at 800–1 100 °C (oxygen blown entrained flow gasification may reach 1 400–2000 °C) depending on the calorific value and includes a number of chemical reactions to form combustible gas with traces of tar. Ash is often vitrified and separated as solid residue.

The main difference between the pyrolysis and gasification is that by gasification the fixed carbon is also gasified. Gasification plants may be designed as 1- or 2-step processes. The gasifier itself may be either up flow, down flow and entrained flow fixed bed type or for big plants also bubbling or circulating fluid bed types, atmospheric or pressurised when combined with gas-turbines. Sometimes the first step is a drying unit, in other cases a pyrolysis unit. Both pyrolysis and gasification units may be installed in front of coal fired boilers of power plants, which enables co-firing with a very high power-to-heat ratio.

1.6.2. Advantages and disadvantages

Advantages of pyrolysis

- Better retention of heavy metals in the char than in ash from combustion. (at 600°C process temperature the retention is as follows: 100 % chromium, 95 % copper, 92 % lead, 89 % zinc, 87 % nickel and 70 % cadmium)
- Low leaching of heavy metals from deposition of the solid fraction chromium and reduced to 20 % for cadmium and nickel
- Production of gas with a LCV (low calorific value) of 8 MJ/kg (10–12 $MJ/Nm^{3)}$, which can be combusted in a compact combustion chamber with short retention time and very low emissions
- CO_2 neutral energy production substituting combustion of fossil fuels
- Less quantity of flue gas than from conventional incineration
- Hydrochloric acid can be retained in or distilled from the solid residue
- No formation of dioxins and furans
- The process is well suited to difficult waste fractions
- Production of sterile clinker and other residues.

Disadvantages of pyrolysis

- Waste must be shredded or sorted before entering the pyrolysis unit to prevent blockage of the feed and transport systems
- Pyrolytic oils/tars contain toxic and carcinogenic compounds, which normally will be decomposed through the process
- The solid residue contains about 20–30 % of the calorific value of the primary fuel (MSW), which however can be utilised in a following combustion zone (incineration/gasification plant)
- Relative high cost
- Back-up fuel supply is required at least during start-up.

Advantages of gasification

- High degree of recovery and good use of the waste as an energy resource (energy recovery with high efficiency of up to 85 % can be achieved, if generating combined heat and power or heat only, electricity gain of 25–35 % is possible)
- CO_2 neutral energy production, substituting combustion of fossil fuels
- Better retention of heavy metals in the ash compared to other combustion processes especially for chromium, copper and nickel
- Low leaching of heavy metals from deposits of the (vitrified) solid fraction particularly for chromium and also reduced for cadmium and
- nickel,
- Production of sterile clinker and other residues
- Production of gas with a LCV (low calorific value) of 5 MJ/Nm^3 (airblown) or 10 MJ/Nm^3 (oxygen-blown) which can be combusted in a compact combustion chamber with a short retention time resulting in very low emissions (alternatively it can be cleaned for tar particles and used in a lean-burn internal combustion engine);
- Less quantity of flue gas than that from conventional incineration
- Gas cleaning systems can remove dust, PAH, hydrochloric acid, HF, SO_2 etc., from the produced gas resulting in low emissions

- The process is well suited to contaminated wood.

Disadvantages of gasification
- Waste must be shredded or sorted before entering the gasifier unit to prevent blockage of the feed and transport systems;
- The gas contains traces of tars containing toxic and carcinogenic compounds which may contaminate the quench water resulting in the need to re-circulate washing water or treat as chemical waste;
- Complicated gas clean-up for motor use;
- The combustion of product gas generates NO_x;
- The solid residue may contain some unprocessed carbon in the ash;
- High cost;
- Only very few non prototype-like plants are available on the market.

1.6.3. Typical costs

A plant normally consists of two or more lines. The costs shown in Table 8 are stated for a highly sophisticated integrated pyrolyse-gasification plant.

Table 8 **Costs relating to an integrated pyrolyse-gasification plant**

Economic information		
Capacity (tonnes per annum)	Typical capital costs Note 1 (EUR)	Typical operating costs Note 2 (EUR)
20 000	(8)–15 million	(0.8) million p.a.
50 000	35 million	1.2 million p.a.
100 000	60 million	2.1 million p.a.
200 000	90–100 million	3.3 million p.a.

Note 1: Plant cost excluding tax, planning and design fee and land based on Danish conditions. In central Europe the cost of plants is approximately a factor 1.5–2 higher, especially in Germany (MCOS/Cowi, 1999).
Note 2: Operating costs excluding the costs of transport, residue disposal, staff costs, income from sales of residue/by products and incomes from sales of energy. Operating cost includes chemical cost e.g. for oxygen, natural gas, nitrogen and limestone and yearly maintenance cost of 3 % of initial capital cost (MCOS/Cowi, 1999).

The number of staff required is 25–40, depending on process, site, size and number of administrative staff situated at the plant. The cost for a simple biomass gasification plant for wood waste is about EUR 1 million per MJ/s waste based on 45 % moisture on weight basis.

1.6.4. Suitability for diverting BMW away from landfill

Pyrolysis and gasification of the organic wet fraction of biodegradable waste alone is unusual, as this would need expensive pre-drying of the waste. The processes are more suitable for the dry fraction of the biodegradable waste but would still have to meet the strict emissions regulations set for incineration plants treating municipal solid waste.

Gasification of chipped park waste (wood chips), can be carried out in relatively simple gasification plants designed for biomass, with low emissions. Gasification of other waste fractions and mixtures will increase the complexity and cost of the plant considerably. Gasification can be considered as a treatment method, provided that a stable market for the produced energy and recyclable products is available.

Gasification of selected waste fractions is environmentally sound with low greenhouse gas emissions compared with, for example, composting and conventional incineration, where gasification can be considered as a refined incineration process. Pyrolysis can be considered as a treatment method for contaminated waste fractions such as car shredder waste, plastics and pressure impregnated wood. It is expected that pyrolysis and gasification plants will have a wider application field in the future due to environmental reasons and the flexibility of the systems which can be combined with other new or existing combined heat and power plants.

2. Quality and market issues

2.1. Introduction

Adequate and reliable markets for good quality compost, energy and other products from waste treatment are essential to prevent biodegradable waste from going to landfills. Market potential must be thoroughly investigated before decisions are made about waste management systems, but market research unfortunately has the obvious disadvantage of being time dependent and rapid changes in preconditions might change a market radically. However, a basic knowledge about markets will often prevent the effects of changes from being fatal. Energy markets have so far been unlimited.

The following chapter assumes that all products can be considered marketable, though some might have a negative price. All products have to meet quality standards to be both acceptable to the environment and to the consumer. This chapter focuses mainly on products destined for plant growth because of the growing attention that such matters are receiving at European level, in particular:

- the plans for an EU compost directive (working document on biological treatment of biowaste);
- the revision of the EU sewage sludge directive;
- the development of CEN-standards for soil improvers and growth media (including compost), resulting in standards for pH, EC, OM, DM and density (CEN 1999a,b,c,d);
- the EU eco-label for soil improvers and growing media (European Commission, 2001).

2.2. Compost and solids from anaerobic digestion

2.2.1. Compost quality

Compost of high quality can be produced by simple technology whereas good process management eliminates problems with malodour, handling properties, weeds or pathogens. A consistently good source separation of BMW and the use of paper bags, and/or buckets eliminate problems with visible impurities, heavy metals or organic pollutants (e.g., the plastic softener DEHP).

Choice of composting plant type is mainly governed by the need to avoid potential odour and vector problems, the limitations in the size of the available area, and the desire to treat an expanding range of waste types in the future. The most efficient/quickest elimination of pathogens is normally achieved with forced aeration treatment.

Compost has to be used in the right amount at the right time of year depending upon the type of compost and application area. Characteristics such as degree of stability and electrical conductivity are very important in determining possible areas of application.

Future estimates of waste quantities and the area needed for compost storage are very often underestimated. Good process management is very difficult under these conditions and most often result in low quality compost and loss of market share. A single batch of bad compost can have a long-lasting devastating effect on the reputation of a plant and should be disposed of.

2.2.2. Compost marketing

The vast majority of composting plants are not actively marketing their products compared with, for example, companies marketing phosphorous fertilisers or peat. Marketing towards the agricultural and horticultural sectors (including private gardens) requires knowledge of plant growing requirements as well as an understanding of the needs of the different sectors. Quality declarations must be comparable with those of competing products.

Additional information regarding application etc., is necessary and the specific advantages of compost over other products should be pointed out such as:

- a high content of beneficial micro-organisms (for improved top soil structure, inhibition of plant diseases, furthering of mycorrhiza);
- a source of stable humus;
- no weeds;
- a liming effect and a slow release nitrogen fertiliser effect.

The fibres produced by many anaerobic digestion processes differ from compost in three ways:

- the content of ammonia-nitrogen is high;
- the degree of stability is low;
- only a few species of micro-organisms are present.

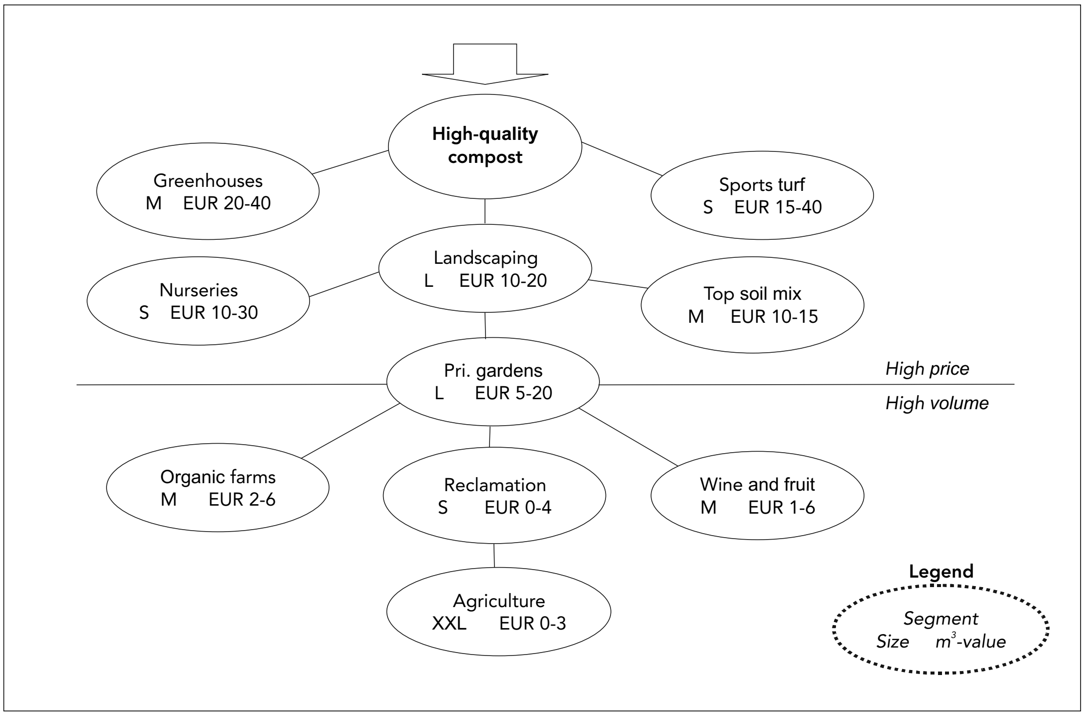
The fibres are best suited for agricultural usage, while a post-treatment composting stage is needed for general marketing in other sectors.

Knowledge concerning the seasons for compost application and focusing on possible terms of delivery is important for the timing of campaigns. A marketing plan must include some degree of personal contact between the composting plant's agronomist and the compost users.

The agricultural market is very important in regions where there is a large and rapidly expanding production of compost. The highest possible nutrient content of the compost is normative for its value within this market.

Compost low in nutrients, e.g., pure garden waste compost, is very well suited for the landscaping sector and for all sectors using compost as mulch. The demand for garden waste compost is substantial within metropolitan areas and for infrastructure constructions (e.g. vegetated areas, road verges). Present sizes of the different markets are shown in Table 9 for four European countries and the attainable price and relative market size (small to extra-extra large) available within the different sectors are illustrated in Figure 1.

Figure 1 **Attainable price and market size**



The prices listed in Figure 1 are actual prices for ready-to-use products with compost, or pure composts, when the producer sells the products to the wholesaler or to the end user *(F. Amlinger, pers. comm.; J. Barth, pers. comm.; W. Devliegher, pers. comm., Carlsbæk and Brøgger, 1995; Domela, 2000).*

Real sizes of markets Table 9

	Austria	Denmark	Flanders, B	Germany
Marketed amount (1996–98 average)				
Compost amount (1 000 tonnes)	300	280	201	4 100
Population size (mill.)	8	6	5	82
Input materials (1996-98 average in % w/w)				
BMW	51	7	21	41
Garden waste	26	88	79	59
Dewatered sewage sludge, others	23	5	0	0
Segments (% of total marketed amount in 1998)				
Private gardens	20	49	18	16
Park and landscaping, reclamation	35	34	50	37
Horticulture, greenhouses	10	2	20	12
Agriculture	30	10	12	32
Others	5	5	0	3

References: Domela, 2000; VLACO, 1999; Devliegher, 1999; F. Amlinger, pers.comm.; J. Barth, pers.comm.; W. Devliegher, pers. comm.

2.2.3. Agriculture and silviculture

The agricultural sector is a very large market paying low prices. The sector may be willing to pay for the nutrients available in compost if there is no surplus animal manure available in the neighbouring area. Organic agriculture often pays more for compost products as compared with high-input agriculture. The nutrient content of composted BMW can be high thus paying for transportation to and application on farmland up to 20–40 km away. Farmers only apply the compost for a short period during both spring and autumn, which is a key consideration when developing a production and marketing plan for a plant.

Organic farming is dependent upon supplementary phosphorous and potassium nutrients from external sources, especially when growing vegetables or if the farm is non (animal) husbandry. Within the agricultural sector, organic farming will pay the highest price for compost (assuming that local supplies of manure are insufficient). The agricultural market is sensitive towards public media discussions, and vegetable growers are often not allowed to use composted BMW due to the food producer's fear of negative consumer reactions. The establishment and maintenance of good connections with the farmers associations and the food producers is therefore recommended. The importance of continuously documenting low heavy metal content and pathogen inactivation cannot be underestimated.

A declaration targeted at the agricultural sector should comprise information about N-total, ammonia-N, nitrate-N, N-available 1. yr. (Spring, Autumn-application), P-total, K-total, Mg-total, S-total, liming effect (as $CaCO_3$ or CaO), pH, organic matter, dry matter, volume weight, visible impurities, heavy metals, possible organic pollutants, sanitary treatment and compliance with the content of possible indicator micro-organisms. Nutrient content should be stated in kg/tonne fresh weight compost. For most uses within agriculture a fairly fresh compost is preferable to a very stable compost, since the latter has a lower content of available nitrogen. The user guidelines, i.e. directions for application, should deal with the permitted amounts according to present fertilisation legislation (e.g., max 170 kg N-total per hectare per year). They should also deal with application methods and crops on the area with respect to sanitary treatment/level of indicator micro-organisms. It should be noted that the fibres produced by many anaerobic digestion processes are best applied before sowing and should be lightly worked into the topsoil. If left on the surface, a substantial part of the plant-available nitrogen will evaporate due to a high content of ammonia and a high pH-value.

Silviculture is defined as the commercial growing of trees, other than fruit trees, for timber exploitation purposes and coppicing. Regulations for compost application in silviculture are comparable to those for agricultural application though lower levels of nitrogen are needed. Application of compost is most beneficial in areas with topsoils low in organic matter (< 2 %). The establishment of forest in previous agricultural land, where high rate agricultural production took place within the last few years, does not benefit from any form of fertilisation, nor from organic fertilisers if the organic matter of the soil is sufficient.

2.2.4. Landscaping

The landscaping sector is a very important market for compost products, especially in metropolitan areas. The sector demands stable or very stable composts free of weeds, with a low level of visible impurities and with good handling properties. High prices are paid for refined compost products, e.g., topsoil mixtures/substitutes, mulches for shrubbery, topdressing for lawns and ball playing pitches. Urban topsoil is often of poor quality (low in organic matter, compacted, damaged by usage of all-purpose pesticides) therefore additional sources of humus and beneficial micro-organisms are desirable. The extended use of woody plants within this sector makes the slow release of fertiliser properties of compost an advantage. Generally, the sector prefers composts low in nutrients for most uses. Some plant species used in landscaping are sensitive to chloride and prefer low pH.

A general compost declaration for the landscaping sector should comprise the same information as for agriculture, except for nutrient content being stated in kg/m^3 and not kg/tonne. Information about electrical conductivity, content of weeds and degree of stability must be added. Mulches should have a content below 10 % (w/w) of particles < 5 mm (Carlsbæk, 1997a; BGK, 2000).

Terms of delivery (delivery within one or a few days) are very important when dealing with the landscaping market. Detailed guidelines are very important when marketing compost for the landscape sector. Recommended use for establishment tasks as well as for maintenance tasks must be stated, including possible need for supplementary nitrogen.

The reclamation of former landfills and mines, or soil sanitation of leftovers/debris from mining, can consume large amounts of, mostly, locally produced compost within a short period of time. Recommendations for soil improvement and the production of topsoil mixes with compost also apply for reclamation purposes. The landscaping market is dependent upon the level of construction activity in the region.

2.2.5. Private gardens and homes

Compost with a high content of nutrients is best suited for vegetable growing, while pure garden waste compost is well suited for perennials, bushes and trees. Many municipality-owned composting plants consider that returning compost made from the collected waste back to the households that supplied the waste is important because it encourages people to continue their participation in source separation and separate collection schemes.

Pricing of compost marketed towards the private garden sector is mostly politically controlled. Regional campaigns in spring with low (subsidised) product/transportation prices or 'pick up a trailer full of compost for free' are very successful and can result in outlets of amounts greater than during the rest of the year. Compost for private collection is often distributed to local locations ('recycling depots', 'Waste centres') to avoid any disturbance of the production including possible accidents as well as a way to lower the overall energy consumption for transportation.

Compost for the private garden sector must be of high visual quality and without malodours. Finely screened compost is more easily marketed than coarsely screened compost. A short guide with simple application hints is very important. Nutrient contents should be stated in kg/m^3. To ensure maximum environmental benefit it should be mentioned, that the use of compost renders any fertilisation with phosphorous and potassium (including NPK-fertilisers) superfluous. However, for low nutrient composts like garden compost, the application of additional nitrogen is still needed for the growing of vegetables and a few other plant types such as roses.

2.2.6. Fruit and wine growing

In wine growing, mulching is fairly common for soil improvement, for reduction of water evaporation and to suppress annual weeds. Composts with a very low nutrient content and a very low content of particles (< 5 mm) are best suited for mulching. The continuous but slow degradation of the mulch will supply the wine with most of the needed nutrients.

The growing of apples, pears and most stone fruits requires large quantities of potassium. The maintenance of a topsoil with a high pH is desirable. Using compost can fulfil both needs. The ground below the tree rows are kept free of weeds by the use of herbicides in high input horticulture, and by weeding or mulching with, for example, garden compost in organic horticulture. Berries have very different needs regarding nutrient levels and pH from fruit trees such as apples and pears and are often very sensitive to chloride. For berry growing, only a very small yearly supply of compost can be recommended.

The declarations on composts to be used in fruit and wine growing should contain the same information as for similar use in the landscape sector. Suggestions and information about machinery needed for the application of mulches are valuable, and a possibility to sub-let the needed machinery from the composting plant will be a competitive advantage in the marketing of compost.

2.2.7. Nurseries and greenhouses

The nursery sector can be divided into plants growing in fields and plants growing in containers/pots, and both ways of plant growing can benefit from the use of compost. Field nurseries need a supply of nutrients and of humus. They are experiencing increasing soil structural problems due to the continuing removal of both plant tops and most of the plant root system. The type of declaration needed and user directions are the same as for the agricultural sector.

Container nurseries are interested in improved growth media and it can be a well paying niche for compost producers. The compost must be of uniform high quality, stable with good structural qualities, and guaranteed free of phytotoxic elements, pathogens, weeds and visible impurities. The slow release nutrient properties of compost are valued. The declaration must include all traditional analyses of growth media, including a number of soluble/plant available nutrients. The total and available content of chloride Cl^- must be sufficiently low not to cause problems.

A few ready-made blends comparable to the traditionally used growth media are best marketed for the container-nursery niche. Physical parameters like air-filled porosity and water retention must be checked for short-term and long-term compliance with the standards and growth performance trials before marketing is recommended. Container nurseries are often specialised in growing very few plant species and know the exact needs of these species. The growth media producer must account for this. Nurseries are experiencing increasing problems with root pathogens which cannot be eliminated by use of fungicides. Disease suppressing properties are inherent in several types of compost, which can be useful to the nursery sector (Hoitink et al., 1997).

The professional greenhouse sector is probably the most difficult sector for compost products to enter with its very high demands for uniformity, quality and documentation. The greenhouse sector pays high prices for the right product, but the costs of product development and marketing are also high. The type of declarations needed for this sector are the same as those needed for the nursery sector, though often only one plant species is grown. The quality requirements for growth media to be used in hobby greenhouses or for potted indoor plants in private houses are lower, but this is counterbalanced by high packing costs and low-paying middlemen.

2.2.8. Slurry from anaerobic digestion

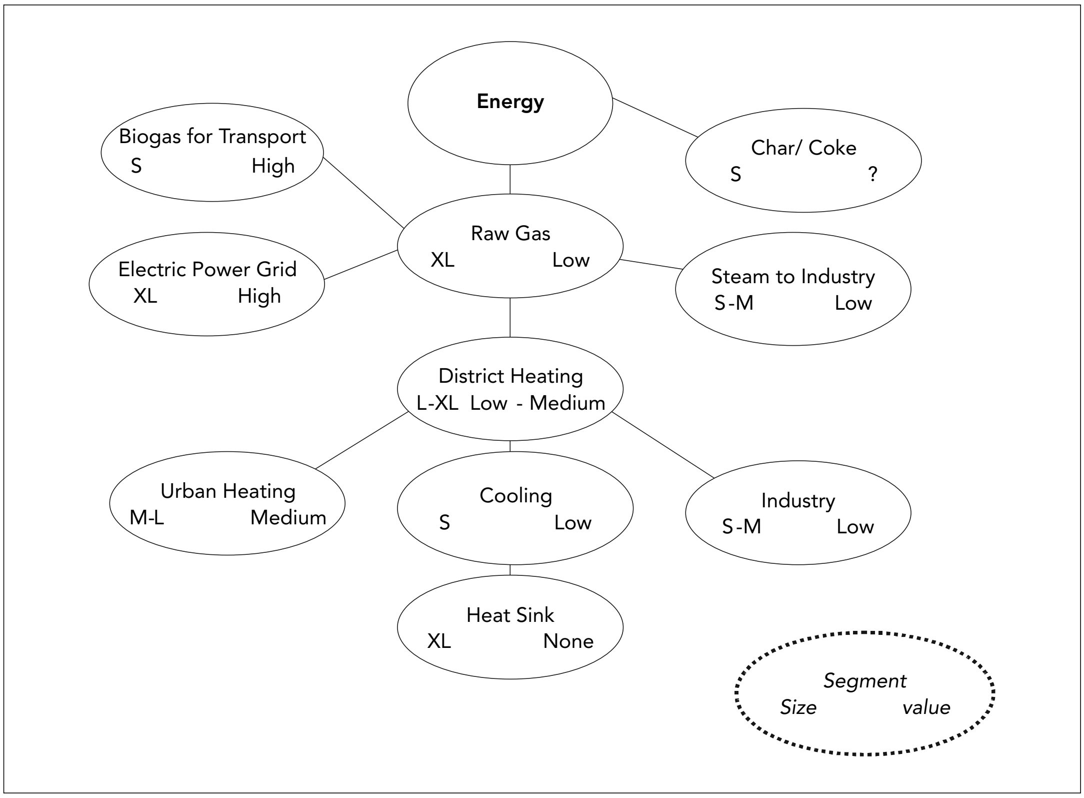
Slurry from anaerobic digestion is used in agriculture only. Due to a low content of nutrients per tonne, the slurry should be used on farms situated within a radius of 5–10 km from the anaerobic digestion facility. If the fibre fraction of the slurry is separated, the remaining thin slurry must be used on neighbouring farms; some facilities choose to discharge such slurry. A very large part of the nitrogen in digested slurry is ammonia and the pH of slurry is high. The use of the right application equipment and avoiding windy and sunny weather, when applying the slurry is therefore very important to avoid high losses of ammonia-nitrogen. Slurry from anaerobic digestion is declared for content of N-total, ammonia-N, P-total, K-total, Mg-total, S-total, liming effect (as $CaCO_3$ or CaO) pH, dry matter, organic matter, visible impurities, heavy metals, possible organic pollutants, sanitary treatment and compliance with the content of possible indicator micro-organisms. Nutrient content is stated in kg/tonne. For general considerations, see the section on marketing of compost for agriculture.

The fibres are best suited for agricultural usage, while a post-treatment composting stage is needed for general marketing into other sectors.

2.3. Energy

There are several ways of utilising energy produced from the treatment of BMW. An overview is provided in Figure 2 below, with an indication of market size (small to extra-large) and value. In the following paragraphs, the various markets for energy in different sectors are described.

Figure 2 **Overview of energy use**



2.3.1. Gas

Biogas may be used in a gas-engine or boiler at the biogas plant. Biogas can be added to the natural gas network after expensive and comprehensive gas treatment to meet natural gas quality standards. Another option is to supply an isolated network with biogas using a controlled mixture of natural gas and air as back-up. Biogas can also be compressed and used as fuel for public transport (buses).

Raw product gas from pyrolysis and gasification is not suitable for distribution. A consumer of pyrolysis or raw product gas from gasification of waste must therefore be located adjacent to the plant in order to avoid condensation of tarry substances in the pipes. The gas can be used on site, for example in a steam boiler for incineration under controlled conditions.

Contrary to pyrolysis gas, cleaned product or synthesis gas can — as for biogas — be distributed several kilometres in separate pipes and used to power an engine or even a gas turbine, but clean-up demands are very strict. Gas clean-up normally results in contaminated wastewater as a by-product, which also needs cleaning or may be returned to the process. Strict safety measures must be taken if product gas is distributed, due to the high content of carbon monoxide in the product gas. In some cases emissions of nitrogen oxides NO_x and unburned hydrocarbons may be a limiting factor depending on local legislation.

2.3.2. Electric power

It is possible to produce electricity from biogas and thermal waste treatment processes but reliable consumers with a known demand are required. Power generation can have a large impact on plant economics but this depends on tariff structures, possible subsidies, contracts for the supply of electricity to a consumer or the public power utility/ distribution company/ power procurer. Electric power production can normally be sold to the public grid, but the price, which can be obtained, depends largely on political criteria.

The power procurer is responsible for ensuring a power production meeting the power needs of a geographic area. Any contract for the supply of electricity will be arranged through negotiations with this body meaning that a competitive electricity market will exist. The price for electricity under this regime will tend towards the lowest possible price, thus encouraging only the most modern and efficient generation methods. The pool price for electricity is presently often in the range of EUR 25–35 /MWh. This price will serve as a benchmark for the negotiations. If power can be sold directly to a consumer or in countries, where non-fossil fuel utilisation (e.g. biogas) is subsidised, a payment of around EUR 50 /MWh may be achieved.

The potential revenue from sales of electricity from a treatment plant ranges typically from EUR 15 to 25 per tonne of waste, based on a net electric efficiency of 20 % and a lower calorific value of 10 MJ/kg. Compared with a gate fee of say EUR 40 per tonne for a modern WTE facility, the significance of this revenue source to the facility is apparent. The grid connection costs depend largely on the actual site location and whether the size of the plant fits the conditions and capacity of the present grid.

2.3.3. District heating

The market for heat is dependent on housing and/or industries, which can be connected to a district heating system. The economic viability of a district heating project is dependent on the location, the distance from the incinerator to the consumers, tariff structures and the heat prices of the actual market. Depending on location, housing for 20 000 people and office complexes and shops with 15–18 000 employees could represent a heat market of more than 100 000 MWh per year.

District heating may be a main product, provided that there is a sufficient heat market and an existing district-heating scheme. For new plants it is necessary to establish a district heating network, central peak load and back-up boilers. Existing supply with natural gas may inhibit the development of a district-heating scheme. If a new district-heating network has to be established the income from selling heat to the network is normally very low due to the capital cost for the network.

District heating temperatures are normally 90/45°C flow and return temperature in winter and 70/50°C during summer. District heating can also drive absorption chilling machines for cooling purposes during summer months or for industrial use and cold stores (not freezing). Waste heat in excess of demand, for example, in the summer, must be discharged using a nearby water stream or air-cooled coils. Waste heat may to some extend also be used to dry incoming waste, for example, sewage sludge, in cases where the moisture content is high.

2.3.4. Steam for process heating

Dry saturated steam can be supplied to a nearby industry as process heating provided that there is a market. Steam is normally needed at 6–10 bar and cannot be transported over longer distances due to pressure loss in the piping system. If condensate is not returned it implies a cost for water treatment for the make-up water. Returned condensate may contain harmful impurities for the steam cycle. It should be noted that steam supply to an external user results in a reduction of the electricity output from the turbine, especially in the case of condensing turbines. The potential outputs should therefore be balanced carefully in order to maximise the plant's revenue from sales of energy. The value of steam for process heating is typically negotiated with each customer and is therefore less quantifiable than the value of, for example, electricity.

2.3.5. Char/pyrolysis coke

Char from waste pyrolysis itself can be used as fuel in a waste incinerator. If inert material and solids are separated from the char it may be blown directly into the furnace of a waste incinerator (e.g. as demonstrated at the Haslev Plant in Denmark), or, alternatively, coal dust burners can be used. The combustion characteristics of the char are similar to pulverised bituminous coal. However, in Germany at present char from pyrolysis units is being disposed of or used for co-combustion in coal fired power plants. Future EU limits on maximum allowable proportions in landfilled waste will rule out the deposition of char in landfill sites.

Some producers claim that their washed char product after de-watering can be delivered to and used in cement kilns. However, until now this has been done at zero cost. Cement manufacturers present very strict acceptance criteria in relation to chlorine and alkali metals as they form a swelling gel together with silica, which can cause micro cracks in the concrete. A Danish cement manufacturer has set the following limits:

Sodium:	*Max. 0.18 mg Na_2O per kg of coke (25 MJ/kg).*
Potassium:	*Max. 0.8 mg K_2O per kg of coke (25 MJ/kg).*
Sulphur:	*0.4 -0.5 % on weight basis.*
Chlorine:	*0.005 % on weight basis.*

The produced char (or part stream thereof) may also be activated to produce activated carbon for use in flue gas cleaning of the plant itself or associated mass burn WTE incinerators. The value of activated carbon is high, about EUR 1 000 per tonne depending on the quality. However, the market for this product is relatively small.

2.4. Recyclable products from incineration and gasification

The value of all of the recyclable materials from any process will depend principally on the existence or otherwise of a market for materials. In order to find a use and market, the quality of a particular material needs to be matched to its application. Certain applications may be more suitable than others with a degree of testing and evaluation being required in all cases. The higher the quality of the material, the greater its usefulness and value, but to achieve this level an amount of refining will be necessary, reducing the net benefit to the producer. The final value of any product will be established only after a period of active marketing and trials whereby potential users may be informed and convinced of its worth. The following products are being recycled successfully at various locations:

- **washed and granulated slag/clinker** can be recycled in road construction projects as a sub-base material and also in the cement industry as a filler material. The inert slag/clinker will meet competition from the existing gravel pit, which normally can produce sufficient amounts at low cost i.e. about EUR 0.5 per tonne. Recycling of construction waste will also generate considerable amounts of gravel;
- **grit, glass and ceramics** can be recycled for back filling (dams, quarries). The value of the mixture is estimated to about EUR 2 per tonne. The value of mixed coloured glass is roughly EUR 1 per tonne;
- **ferrous metal** can be recycled to an iron smelt with a value of about EUR 10 per tonne;
- **non-ferrous metal,** especially copper and aluminium, can be recycled for smelting, but the value is very dependent on the amount of impurities as e.g. chrome. Recovered metals can be sold to the local scrap market, at market price, if the materials are considered to be of

sufficiently high quality. It is preferable to source separate metal instead of separating copper, aluminium and glass/ceramics from the slag;

- **chemical bulk**. In some cases $CaSO_4$ for gypsum board production can be produced or HCl for acid production.

2.5. Residuals from incineration

Fly ash and dry flue gas cleaning products are hazardous wastes that have to be disposed of in a controlled and environmentally acceptable manner. Sludge from flue gas cleaning products is normally treated as fly ash and often mixed and stabilised with fly ash or lime for deposition at, for instance, a hazardous waste landfill, with a dryness of 65 % dry matter. Wastewater must be fed to a water treatment plant, which will typically be part of the overall facility.

2.6. Overview of markets and products

Selection of appropriate treatment methods for biodegradable waste should be based on the criteria mentioned in Section 5.1 including an evaluation of the possible markets in the particular planning area. Table 10 provides an overview of the market options related to the products that may result from various treatments.

Overview of market options Table 10

Product	Market options
Compost	Agriculture; forestry; fruit and wine gardens; plant nurseries; private gardens; parks; landscaping; ground rehabilitation
Fibre fraction (anaerobic digestion)	Agriculture; forestry; ground rehabilitation
Liquid fertiliser	Agriculture
Electricity	Ordinary power supply system; industry
Steam	Electricity production; industry
Heated water	Ordinary district heating systems; industry
Clinker	Construction industry; civil works
Grit, glass and slag	Civil works; ground rehabilitation

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