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Introduction

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1.1

Introduction to Waste Management

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Solid waste management is as old as human civilization, although only considered an engineering discipline for about one century. The change from the previous focus on public cleansing of the cities to modern waste management was primarily driven by industrialization, which introduced new materials and chemicals, dramatically changing the types and composition of waste, and by urbanization making waste management in urban areas a complicated and costly logistic operation.

This book focuses on waste that commonly appears in the municipal waste management system. This chapter gives an introduction to modern waste management, including issues as waste definition, problems associated with waste, waste management criteria and approaches to waste management. Later chapters introduce aspects of engineering (Chapter 1.2), economics (Chapter 1.3) and regulation (Chapter 1.4).

1.1.1 Defining Solid Waste

1.1.1.1 Waste

A simple definition of waste is:

'Waste is a left-over, a redundant product or material of no or marginal value for the owner and which the owner wants to discard.'

An important characteristic is that being 'waste' is not an intrinsic property of an item but depends on the situation in which the item appears as defined by its owner or in other words how the owner values the item. The owner sees little value in an item if the effort required converting the excessive item to cash value or preserving the item for future use or consumption exceeds the effort it takes to obtain the same cash value or function of the item by other means. Then the item becomes waste. This means that becoming 'waste' may depend on many factors, for example:

- **Time:** If supplies are scarce, for example during war time and embargos, the owner will spend more time and effort repairing an item since the alternative may be costly and hard to find.

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- Location: Farming communities may easily make use of food waste for animal feeding, while this is less feasible in a highrise in an urban area.
- State: The item may be repairable depending on its state (price, age, type of damage) and thereby avoid being discarded.
- Income level: The higher your income the more food you may discard or the more items you may discard because they no longer are in fashion or up to date.
- Personal preferences: Certain types of items may be collector's items or possess veneration for some individuals.

This also suggests that what is waste to one person may not be waste to another person and there may be a potential for trading if the cost for transferring the item does not exceed the value of the item as perceived by the new owner. Hence quantity and purity of the item is a key issue; the metallic paper clip in a private household may be discarded as waste, while tonnes of iron cuttings in a manufacturing industry may not be a waste but a secondary product that can be traded.

In addition to the abovementioned factors, what actually becomes waste depends on which items are being purchased and consumed. Or in other words culture, climate, religious and ethnic background as well as economical abilities affect what becomes waste. Hence, waste quantities and composition vary widely, both geographically (regionally, locally) and over time.

The introduced definition of waste may teach us about the complexity of waste, but the definition may not suffice in a legal context, since it has a high degree of subjectivity. The European Union (EU) defines waste as 'any substance or object which the holder discards or intends or is required to discard' (CEC, 2008). The authorities can define what is to be considered as waste; thereby controlling what is regulated as waste. The EU definition is supplemented with a long list of items and materials as examples of what can become waste, often referred to as the European Waste Catalogue.

1.1.1.2 Solid Waste

The definition of 'solid waste' would be anticipated to be 'a waste in a solid state'. However, solid waste may be solid, or liquid as a sludge or as a free chemical phase. This originates from defining solid waste as waste that is not water (wastewater) or air borne (flue gasses). This also suggests that solid waste has no transporting media like water and air that must be cleaned. While obtaining clean water and clean air are the main purposes of treating wastewater and cleaning flue gasses, the purpose of waste management is not to clean the waste bins, but to handle the waste in the bins, as discussed later.

Solid waste is mostly in a solid state, but also sludge from wastewater treatment and liquid chemical waste are included, although the latter are not within focus of this book.

1.1.1.3 Hazardous versus Nonhazardous Waste

It is often convenient to distinguish between nonhazardous waste and hazardous waste. This may apply to practical waste management as well as to the regulatory aspects of waste management. Hazardous waste is more dangerous to the environment and to those handling the waste and must be technically managed with more strict controls than nonhazardous waste.

The hazardousness of a waste is assessed according to criteria as (simplified after CEC, 2008):

- Explosive under the effect of flame, shock or friction.
- Oxidizing in contact with other materials resulting in highly exothermic reactions.
- Flammable in contact with air having flashpoint less than 55 °C (highly flammable, with a flashpoint less than 21 °C).
- Irritant: causing inflammation through contact with skin or mucous membrane.
- Harmful: causing limited health risks through inhalation, ingestion or penetration of skin.
- Toxic: causing serious, acute or chronic health risks and even death through inhalation, ingestion or penetration of skin.
- Carcinogenic: inducing cancer or increasing cancer incidence through inhalation, ingestion or penetration of skin.
- Corrosive by destroying living tissue on contacts.

- Infectious due to viable microorganism or their toxins known or reliably believed to cause disease in man or other living organisms.
- ‘Toxic for reproduction’: substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce nonhereditary congenital malformations or increase their incidence.
- Mutagenic: inducing hereditary genetic defects or increasing their incidence through inhalation, ingestion or penetration of skin.
- Releasing toxic gases in contact with water, air or an acid.
- ‘Sensitizing’: substances and preparations which, if they are inhaled or if they penetrate the skin, are capable of eliciting a reaction of hypersensitization such that on further exposure to the substance or preparation, characteristic adverse effects are produced.
- Ecotoxic: presenting any immediate or delayed risks for any sector of the environment.
- Substances capable by any means after disposal of yielding another substance which possesses any of the characteristics listed above.

These criteria are for practical assessments supplemented with quantitative limits as well as methods for their determination (for example, see CEC, 2008, and in particular CEC, 2000).

1.1.2 Material Flow and Waste Generation

Waste generation is linked to economical activities and flow of materials in society.

The schematic diagram in Figure 1.1.1 (adapted from Vesilind *et al.*, 2002) illustrates the flow of materials from the environment through society and back to the environment. The diagram pictures the fact that resources are not consumed but merely transformed in the process of extraction from the environment, production and use before ending up as waste. This waste may be returned back into the production-use cycle in society or disposed of into the environment. The material flow is driven by a significant use of energy, and emissions to air, water and soil are associated with all activities within the flow system. Also the extraction of resources and the disposal of waste into the environment may have associated environmental burdens. A large extraction of resources may also lead to the depletion of resources, for example certain metals; and disposal activities may damage resources by contamination, for example groundwater resources at a landfill.

Modern society is characterized with a very large extraction of resources from the environment and a very large disposal of waste in the environment. As the economy expands, the material flow traditionally also expands, leading to

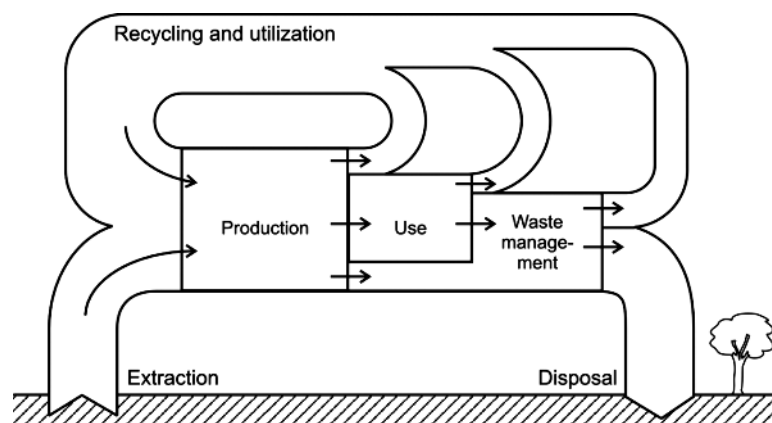


Figure 1.1.1 Schematic material flow in society showing extraction of resources, production, use, waste management and disposal into the environment (inspired by Vesilind *et al.*, 2002). Reprinted with permission from *Solid Waste Engineering 1E* by Vesilind, Worrell and Reinhart, 9780534378141 © (2002) Cengage Learning.

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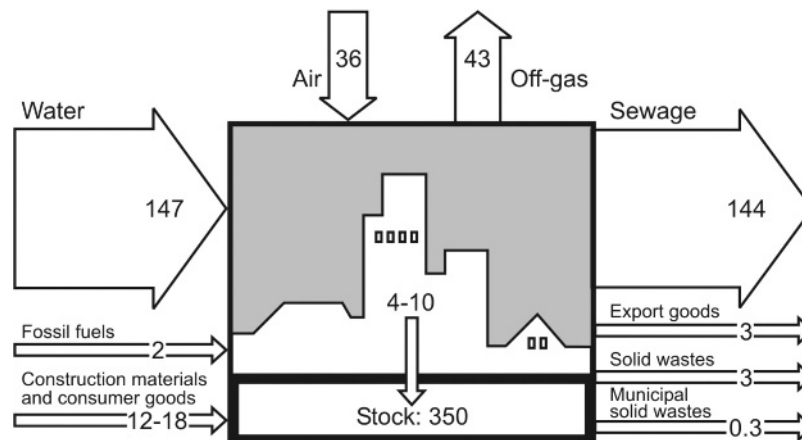


Figure 1.1.2 Mass flows (t/year/person, except for stock which is t/person) estimated for Vienna (based on Brunner and Rechberger, 2004). Reproduced with permission from Lewis Publishers, USA. © (2004) Taylor & Francis Group LLC – Books.

increased environmental burdens and resource consumption. Schematically it may seem possible to link the disposal with the extraction of resources and thereby ‘close the loop’, but the resources mined and the biomasses grown (inputs) are so different from the waste disposed (outputs) that this is neither technical nor economical feasible. The control of the material flow allowing for continued economical expansion, also for the less developed part of the world, is rather linked to a more efficient use of the resources extracted and increased recycling and utilization of the waste generated. This again reduces the amount – at least relatively – being disposed of into the environment.

Figure 1.1.1 neglects the fact that many of the goods produced and consumed have very different retention times in society: Packaging has a very short lifetime (days to weeks), daily consumer products like telephones, clothing, etc. have a moderate lifetime (few years), large consumer products like furniture, vehicles, etc. have a long lifetime (many years to decades), while buildings and civic constructions (e.g. roads) have very long life times (decades to centuries). This implies that waste generation is not directly linked to production and use, since many of the goods produced may accumulate in society and appear as waste at a much later point in time. This was illustrated by Brunner and Rechberger (2004), who estimated flows in and out of the city of Vienna, Austria. Figure 1.1.2 shows estimates for one year in the 1990s, suggesting that the solid material flow in terms of construction materials and consumer goods (excluding energy resources) into the city is of the order of 12–18 t/year/person, while the outputs in terms of export of goods and waste is only 6.3 t/year/person. This suggests that for each person the stock increases by 4–10 t/year, corresponding to 1–3 % of the current stock. The stock is primarily buildings and civic constructions.

The direct material input per person per year (including energy resources) on a country basis is somewhat larger than the input to a city, since mining, industry and agriculture also have large inputs. Figure 1.1.3 shows a plot of the direct material input as a function of gross domestic product (GDP) for a number of countries. In general it appears that a high GDP is associated with a high material input, in the order of 20–50 t/year/person. The link is supposed to be strongest for countries with a basic developing economy, while some countries seem to have decoupled the economic growth from the direct material input. This may be due to economical development in high-tech areas (e.g. telecommunications) or the service sector (e.g. financial sector) or the combination of a decline in heavy industry and mining and growth in sectors with less material consumption. When heavy industry closes down in one country, this may lead to growth in other countries of the same type of industry, thus only moving the material use to another country unless the moving involves introduction of new and resource-saving technologies.

Although it is desirable in the near future to decouple the economic growth from generation of waste – and in the long run it is a must – it seems very difficult to do so. Figure 1.1.4 illustrates that, for a 10-year period where GDP increased by 20 % in Denmark, the index of waste generation per unit of GDP remained constant, while the corresponding index for energy consumption decreased by 15 % and the index for water consumption decreased by 35 %.

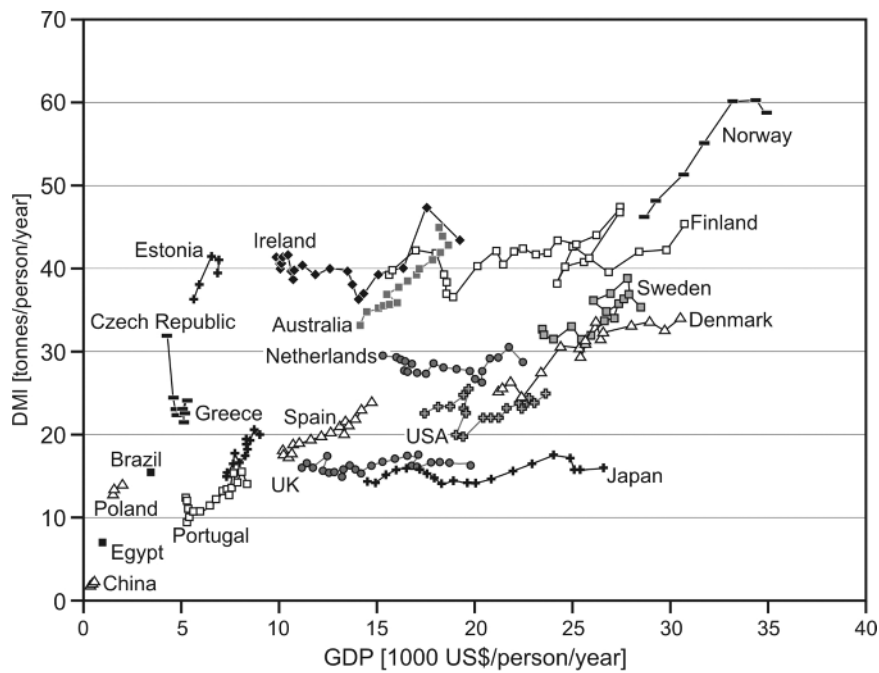


Figure 1.1.3 The relationship between the direct material input (DMI) and the gross domestic product (GDP). Based on Bringezu et al. (2004). Reprinted with permission from *Ecological Economics, International comparison of resource use and its relation to economic growth: The development of total material requirement, direct material inputs and hidden flows and the structure of TMR by S. Bringezu, H. Schultz, S. Steger and J. Baudisch*, 51, 1–2, 97–124 © (2004) Elsevier Ltd.

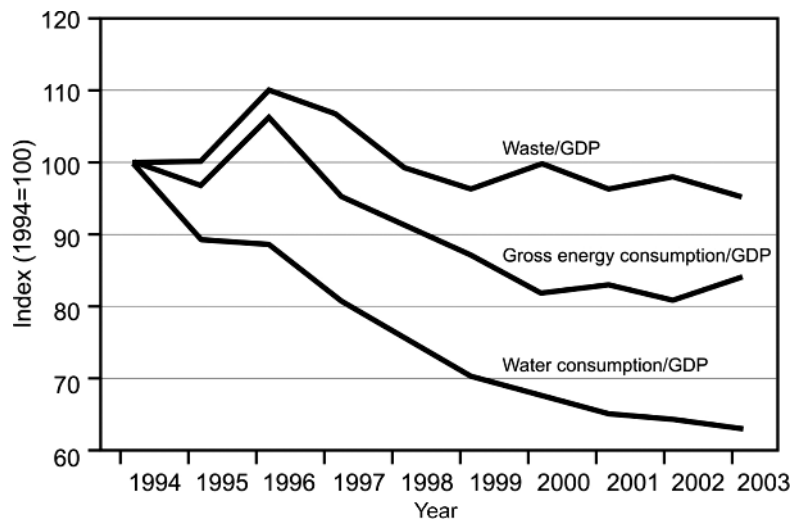


Figure 1.1.4 Index for waste generation, energy consumption and water consumption relative to gross domestic product (GDP) for Denmark for a 10-year period (1994–2003) when the Danish GDP increased by 20 % (based on Danish EPA, 2005).

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1.1.3 Issues Associated with Solid Waste

A range of important issues are associated with solid waste, as discussed below. The listed issues should not constitute a problem if the solid waste is properly managed, but whatever solid waste management system is introduced, its implementation should be made in respect of these issues. The issues are listed in the order as they historically often have emerged and have been addressed, although not all waste management systems around the world are fully addressing all the issues satisfactorily.

- Volume/space: Waste takes up space and does not disappear by itself. Removing waste from premises and public areas is still today the first and main goal of all waste management.
- Nuisances: Where waste accumulates over time because of ineffective waste collection and public cleansing, nuisances such as odors, flies, blowing litter, etc. may develop and become a problem for neighbors and an aesthetic problem for the community.
- Public health issues: Accumulated waste easily accessible by insects, animals and humans, in particular children, may constitute a health issues. Pathogens in the waste may spread by direct or indirect contact (water, air, insects, small rodents) or the waste may enhance the survival and spreading of infected vectors such as rats, seagulls, etc that feed or nest in the waste. Box 1.1.1 discusses further the pathogenic risks associated with solid waste. Health issues may also originate from chemicals in the waste by direct or indirect contact to humans.

Box 1.1.1 Pathogenic Risks Associated with Solid Waste.

Solid waste potentially contains pathogenic risk to humans, although no conclusive epidemiological studies have been found. The lack of evidence is probably due to the fact that, in modern society, humans are so little in direct contact with waste that their exposure to pathogens is very limited and the diseases encountered are few and may not be identified as been related to waste. However, it is important to recognize that potential pathogenic risks exist. There are three different types of pathogenic risks:

- Direct infection through ingestion or skin contact with waste containing pathogens. Kitchen waste, diapers, animal excrements, dead animals and alike may contain pathogens that by contact can infect man. Diseases caused by bacteria, fungi and intestinal worm eggs may be transmitted to humans and cause diarrhea, tetanus and eye infections. Bacteria are here of most importance. The infectious organisms may be coliforms, *Salmonella* or *Staphylococcus*. The main route of infection is through ingestion.
- Direct or indirect contact through infected vectors such as rats, cockroaches, seagulls, flies, etc. that feed on the waste or live in the waste and thereby may carry the pathogens outside the waste when migrating. Rats are believed to be the most important vector because of their interest in waste, their long migration distances and their close contact with human habitats. *Leptospira* may multiply in the kidney of infected rats and through urine the infection may spread to humans through skin abrasions and mucus membranes, causing Weil's disease (Swan *et al.*, 2002). Seagulls may also travel long distances after having fed on the waste, but their contact with humans is more sporadic and primarily through their excrement. Organic waste not infected may also be food for vectors that have acquired the pathogens from other sources, e.g. sewers, and thereby contribute to spreading the pathogens.
- Stored or biologically processed waste may host bacteria, actinomycetes and fungi that, when mechanically disturbed, may spread as dust or aerosols or may release toxins that can cause diseases in humans. These aspects have in particular been investigated in MRFs and composting plants. The related health issues are primarily respiratory: asthma, chronic bronchitis, allergic alveolitis and 'organic dust syndrome' (Swan *et al.*, 2002), but also itching eyes and itching throat appear. Fungi (e.g. *Aspergillus*, *Rhizopus*), mycotoxins (secondary metabolites produced by fungi) and glucans (a polyglucose compound in the cell walls of fungi) are in particular important, but also actinomycetes (primarily their spores) and endotoxins (fragments of the cell wall of Gram-negative bacteria) play a role (Swan *et al.*, 2002). Primarily workers in direct contact with waste or its handling are exposed to these pathogenic risks through exposure to dust and aerosols.

- **Economy:** In urban areas where large quantities of waste must be managed and no easy ways of disposal are available within short distance, the cost of solid waste management become significant. The annual cost may in metropolitan areas be as high as 100 €/person; this corresponds as an order of magnitude to 0.5 % of GDP. The cost issues therefore are important in all waste management.
- **Contamination of the environment:** Waste disposal leads to transfer of substances from the waste to air, water and soil and may cause contamination of the environment: For example groundwater pollution at landfills, air quality affected by air emissions from incineration, metals in soil and crops after compost use. This has in many parts of the world led to stricter and stricter emission controls at waste management facilities.
- **Resource issues:** Waste contains resources that should be used in order to save on other resources. In many parts of the world this is done of economical reasons, for example scavengers and small scale recyclers that are recovering resources from the waste for a living. But resource recovery can also be viewed in the context of avoiding environmental impacts from production of virgin resources and at the same time avoiding environmental impacts from waste disposal. This suggests that resource recovery should not be viewed only in private economical terms.

1.1.4 Waste Management Systems

Although this book primarily focusses on the municipal waste management system, it is important to realize that several systems are dealing with waste or items that could become waste. Municipal solid waste is however not well defined, as described in Box 1.1.2. Six different systems can be conveniently identified:

- **Inhouse waste handling:** ‘Waste’ may be utilized on the premises or in an industrial symbiosis; the latter is when one industry directly uses ‘waste’ from another industry as a resource in its production. For example low quality wood chips could be used for inhouse generation of power. In principle this is not a ‘waste’ according to our definition, but inhouse waste handling could be an important initiative in promoting waste minimization or waste prevention, as later discussed.
- **Littering/unmanaged waste handling:** Common littering in terms of waste thrown away in the countryside, along transportation lines or in public areas is found everywhere, although on a variable scale. Littering is usually in the form of packaging and newspapers, but also infrequently arising waste (such as waste from building renovation and old white goods) may appear ‘dumped’ in the countryside or in derelict areas. Littering and dumped waste may later demand public cleansing of the affected areas and thereby become a part of the public waste management system.
- **Return system:** Used products may be returned to the store where bought or to a similar store depending on business structure. Returnable beverage bottles and cans with a deposit are common. The recovery of the deposit is the economic incentive for the consumer to return the items. Return systems may also exist without deposits as a part of voluntary agreements between environmental authorities and business chains, as an element in the environmental profiling of a branch or as part of legally enforced producer responsibility. Such systems could for example involve batteries, medicine, car tires and electronic equipment.
- **Municipal waste management system (public or private):** Organized handling of municipal waste is usually a public issue, although many of the elements in the system may be privately owned and operated. Municipal waste is the waste that is generated by citizens and civil work and similar waste from small businesses and industry. The public is the governing authority.
- **Industrial waste management system:** The term industrial waste is used for waste of industrial origin that is found in large quantities of special composition or in smaller quantities but hazardous. The latter usually is handled in the hazardous waste management system. Industrial waste is often dealt with case-by-case because the large quantities and special features determine the ways of disposal. Systems for managing the waste at an industry may be an integrated part of the authorities’ environmental approval or licensing of the industry.
- **Hazardous waste management system:** The nature of the hazardous waste calls for special ways and rules of collecting, storing and transporting the waste. Also the treatment and disposal facilities have special features and regulations. This typically leads to a higher cost per tonne than the common cost for municipal solid waste.

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Box 1.1.2 Municipal Solid Waste and its Definition (Based on Tchobanoglous *et al.*, 1993; Strange, 2002; Vesilind *et al.*, 2002).

The definition of municipal solid waste (MSW) varies, but typically ranges from waste arising from private households to that managed by or on behalf of local authorities from any source. MSW therefore includes a proportion of commercial, nonhazardous industrial waste and potentially also demolition waste and sewage sludge. Depending on the country, the definition can include some or all of:

- Household waste.
- Household hazardous waste.
- Bulky waste from households.
- Street sweepings and litter.
- Park and garden waste.
- Waste from institutions, commercial establishments and offices.
- Construction and demolition waste.
- Sewage sludge.

Depending on definitions, a study from 1997 (cited by Strange, 2002) found that the ratio of household waste to municipal waste varied dramatically from 45 % (Norway) to 84 % (Germany). It should be recognized that MSW is a management concept and, since the extent of municipal activities in the waste sector varies widely across countries, data and information referred to as MSW should be used with great care unless clear definitions are provided by the source.

There are other categories of waste that are of importance but usually regulated by specific regulations and not dealt with in this book:

- Agricultural waste.
- Mining and quarry waste.
- Dredged materials.
- Contaminated soils.
- Production-specific industrial waste.
- Ashes from power plants.
- Radioactive waste.
- Waste from warfare.
- Waste from natural disasters.

Municipal solid waste is likely to make up only 10–20 % of the above listed categories of waste.

1.1.5 Waste Management Criteria

The ideal waste management system does probably not exist, but it may be useful to identify some of the main criteria that waste management as service and a public obligation should consider and try to balance. The following criteria should be considered in all waste management planning:

- Provide a customized and robust handling of all waste with a minimum of effort for the customer and the citizen.
- Ensure the lowest possible load on the environment in terms of noise and contamination of air, water and soil.
- Provide a maximum of resource recovery from the waste while minimizing use of resources in the waste handling.
- Be a safe and healthy occupation for the workers offering nonmonotonous work and achievable challenges.
- Provide only little impact on the city with respect to traffic, vehicle exhaust, noise, traffic accidents and spill of waste.
- Include aesthetic and architectural considerations in establishing waste collection and treatment facilities.
- Respect as a minimum current laws, regulations and code of practice.
- Be economically acceptable and fair.

These ideal criteria are partially in conflict: for example, fulfilling environmental criteria increases cost. All waste management systems must identify which criteria are the most important and then reach an acceptable compromise. No simple relation can combine these partly contradictory criteria into one single criterion function to be optimized, unless all criteria are forced into economical terms (see later).

1.1.6 Waste Management Approaches

Waste management decisions take place on many levels, but are characterized by a dominance of local decisions. This also suggests that local conditions, criteria and preferences play an important role in defining the waste management system. However, some main types of approaches have been used extensively or are emerging on the scene, as described below.

1.1.6.1 Common Sense Approach

The common sense approach accepts that some of the mentioned criteria meet defined minimum standards (occupational health, level of service, compatibility with regulations, etc.), while the balancing of the other issues is a matter of discussion among the political decision-makers. Often costs have been the main criteria and often environmental issues have been dealt with in an opinionated way rather than in scientific terms.

1.1.6.2 Waste Hierarchy

The Western world and parts of Asia have since the early 1980s used the *waste hierarchy* as the main approach to waste management. The wording used and the name may vary (In Japan the approach is called 3R, for *reduce, reuse and recover*), but the main message is that priorities in waste management should be:

1. Waste prevention and cleaner technology
2. Reuse
3. Recycling of materials
4. Recovery in terms of material utilization and energy recovery
5. Disposal including landfilling and mass burning without recovery.

The waste hierarchy is a strong approach and easy to communicate and quantify if the purpose is to avoid landfilling, but two aspects are not well addressed by the waste hierarchy. One aspect is that waste minimization and cleaner technology is a very difficult issue for local and regional bodies because they do not have the mandate and power to address this. Waste minimization is primarily a state or interstate issue, since globalized industrial manufacturing and marketing of products must be the focus. The second aspect is that, as energy prices go up and the Kyoto protocol forces many countries to reduce their use of fossil fuel, energy recovery from solid waste may be as beneficial as material recovery and thereby question the rigid prioritization of material recovery over energy recovery.

One example of communicating the goal of waste minimization is by the *zero waste* approach described in Box 1.1.3.

1.1.6.3 Sustainability

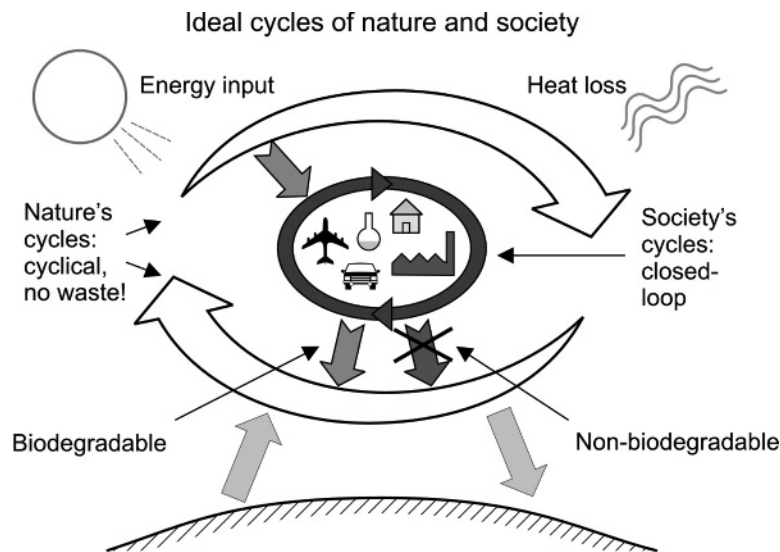
The concept of sustainability was introduced by the World Commission on Environment and Development in 1987 (the Brundtland report, *Our Common Future*, WCED, 1987). Sustainability is defined as: 'Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.' Sustainability has an environmental as well as a social and economical dimension. The definition does not provide much guidance as to waste management, but has fostered a way of thinking suggesting that long-term issues should receive more attention, that each generation should solve its own problems and that local solutions should be sought. The lack of concrete guidance has inhibited the introduction of the sustainability concept in waste management although the word is often used in the

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Box 1.1.3 The Zero Waste Concept.

Several public bodies have set a zero waste policy with a target of zero waste by, for example 2020. Authorities in Australia, New Zealand, Canada, Germany and other countries have introduced this utopian concept (Snow, 2003) as a political goal. The zero waste concept includes the concept of producing less waste, known in the industrial sector as cleaner production. As such the zero waste concept is not new. At the municipality level, the zero waste concept is a catchy message used to improve recycling, composting and other means to utilize waste at the expense of landfill and mass incineration. In practice the zero waste goal is a goal of avoiding the landfilling of waste.

The figure below (based on Zero Waste Alliance, 2001) illustrates the ultimate goal of the zero waste concept: society's consumption and production of goods as a closed loop generates only biodegradable waste.



The concept of zero waste does not put an end to waste as defined in this book, but is a political message focusing on waste minimization and recycling of waste. One could say that zero waste for municipal authorities is just another way of expressing the waste hierarchy – saying we do not want to landfill our waste in future.

context of waste management. The EU landfill directive (CEC, 1999) contains several elements of sustainability although this is not directly said. The EU thematic strategies on waste prevention and recycling (CEC, 2005a) and on the use of natural resources (CEC, 2005b) also pledge for sustainable development related to waste management.

1.1.6.4 Life Cycle Thinking and Life Cycle Assessment

Life cycle assessment (LCA) is a common tool used to evaluate and minimize the environmental impact of industrial products, but is still fairly new in waste management. LCA basically accounts for all mass flows and emissions, as well as energy use and production within the waste management system and any upstream (e.g. lime used in flue gas cleaning) and downstream processes (e.g. recovery of recycled glass). All the emissions and resources used are aggregated into commonly agreed impact categories, as for example global warming and acidification. LCA is a comprehensive accounting system that makes it possible to evaluate alternatives according to defined environmental criteria. LCA in waste management is presented in Chapter 3. Life cycle thinking builds around the same concept as LCA but is less

data-demanding and rigorous and hence easier to introduce. The EU waste directive (CEC, 2008) suggests that life cycle thinking should be introduced in all waste management decision-making, and derogation from the waste hierarchy should be based on life cycle thinking.

1.1.6.5 Environmental Economics

In environmental economics, prices are estimated for all environmental emissions from a system and added to the traditional economical data for the system. The external costs are said to be internalized, i.e. brought into the system by putting a price on them. Thereby all aspects of importance in principle are ascribed an economical value and alternative systems can be assessed in terms of cost as a single parameter. Environmental economics in waste management are further discussed in Chapter 1.3. Environmental economics are just starting to find a role in waste management, most likely on the national level since the external costs often have very little relationship to the local authority. In environmental economics, national boundaries are often chosen as system boundaries and costs distributed in time are discounted, suggesting that future costs associated with waste management have less weight than today's cost. It is evident that environmental economics use assumptions and methods which are very different from the concepts of sustainability and LCA. The sustainability concept accepts emissions today in order to avoid future emissions ('each generation should solve own problems') while environmental economics as a consequence of discounting pay less attention to future emissions than to emissions happening today. LCA considers all emissions induced by the waste management system no matter where they appear, while environmental economics often disregard emissions in foreign countries, assuming that the price for trading goods across a border includes all environmental costs.

1.1.7 Current Waste Management Practice

Although the criteria for waste management are developing, as described above, the management of waste varies significantly among countries. This is due to differences in the waste, availability of land, possibilities for using the materials and energy held in the waste, costs, political focus and national preferences. Worldwide, a lot of municipal waste is not managed in an organized way but is still being dumped, and landfill is definitely still the predominant waste management technology. Even within Europe, major differences appear at the beginning of this millennium, as shown in Figure 1.1.5. Landfill is the predominant technology in more than half the countries covered by the survey, and only in a few countries is more than 25 % of the waste recycled.

1.1.8 Institutions and Roles in Waste Management

Several institutions play a role in governing and developing waste management. These are briefly mentioned here.

1.1.8.1 International Conventions and Protocols

International conventions may address specific issues of importance in waste management. They become an international codex of good practice when a sufficient number of countries have ratified the text of the international convention and implemented it into national legislation. Examples of important conventions:

- The Basel Convention (22 March 1989; UNEP, 1989) provides an international regulation on hazardous waste export and transport, especially putting a ban on exports of hazardous waste from OECD countries to non-OECD countries.
- The Montreal Protocol (16 January 1987; UNEP, 2000) limits the use of chlorinated and fluorinated compounds in consumer products and restricts the emission of these compounds because of their ability to deplete stratospheric ozone. This convention has significantly affected the way that refrigerators and freezers are dismantled today.

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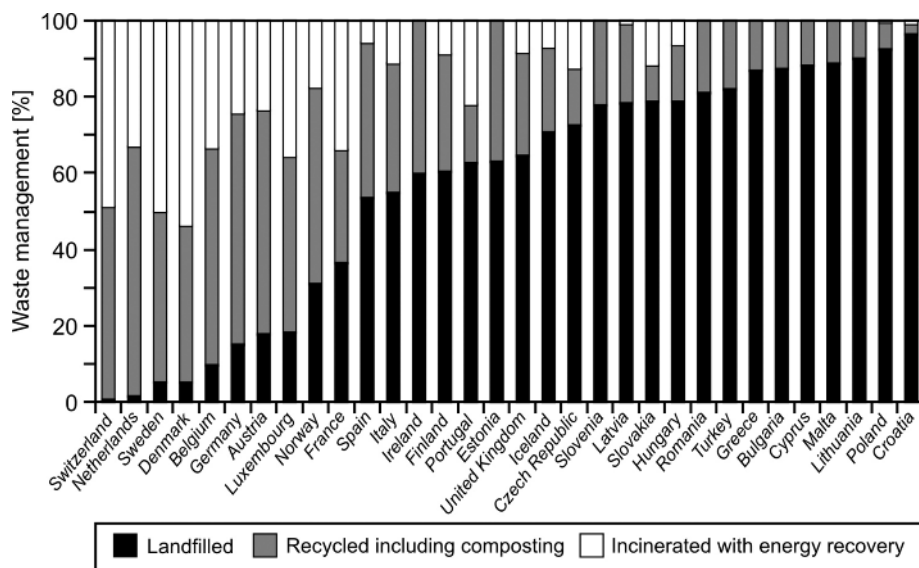


Figure 1.1.5 Residential waste management in Europe (based on data from Eurostat 2007), calculated by the European Topic Center for Waste and Resource Management. Reprinted with permission from Final report to the Directorate General Environment, Costs for municipal waste management in the EU by D. Hogg © (2002) European Commission.

- The Kyoto Protocol (11 December 1997; UN, 1998) commits countries that ratify the protocol to reduce their emissions of greenhouse gases or engage in emission trading.
- The Aarhus Convention (25 June 1998; UNECE, 1998) focusses on public participation, human rights and links government accountability by environmental protection.

1.1.8.2 Federal and European Union Level

Federations and unions, for example the USA and the EU, may within certain areas regulate waste management. This is often in terms of principles to be applied or in terms of minimum standards or goals that must be met. This type of federal regulation often has two purposes: (1) to ensure that all states take measures to establish waste management systems that respect environmental issues and (2) to avoid that any large difference in levels of environmental protection creates so large a difference in waste management fees that waste management costs creates uneven competition between industries and unwanted long distance transports of waste from one country to another due to lower prices.

1.1.8.3 State and Country Level

National or state authorities create the framework for the municipalities, which are the main decision-makers in waste management in most Western countries. The framework may contain specific goals to be achieved, e.g. a certain level of recycling of paper, and specific guidelines as to how planning is done or how facilities should be constructed and operated, e.g. how top covers on landfills can be designed or what they should achieve. State and county often are the approving authority that shall assess and license specific facilities, privately as well as publicly owned. At the state level, taxes can be introduced to economically force waste management towards certain desirable goals.

1.1.8.4 Municipality or Region

Municipalities often have the responsibility to establish systems for waste management including a range of services with sufficient capacity. Municipalities make the concrete decision on source separation as well as treatment and disposal

facilities: type, capacity, location. Consequently they also have the financial responsibility and power to collect fees for using the waste management system. The municipality must of course respect the national legislation and guidelines provided by national authorities, but within this framework they make all major decisions.

1.1.8.5 Producers and Individual Industries and Citizens

As a basic principle, the producer of the waste is responsible for its management until the waste and the responsibility for its management are transferred to an authorized entity, e.g. the municipality or a licensed private company. This transfer is at the cost of the waste producer. This is the *polluter pays* principle and is a common basis for most environmental legislation. This in principle forces the producer, e.g. an industry or private citizen, to act responsible regarding waste in terms of minimizing the waste generated, giving priority to recyclable materials and products and enforcing high-quality source separation of the waste.

The citizen, or actually in most cases the house owner, is often obliged to use the waste collection system offered by the municipality, allowing only a few individual choices as to the number and size of collection bins, garden waste collection and other optional services. However, fully liberal systems also exist, e.g. in Delaware, USA, where the individual house owner may select a waste collecting company among a series of approved companies or may choose to bring by car the waste to local waste transfer stations, paying per bag delivered. This may provide the maximum of individual freedom to choose, but it most likely does not provide the most environmentally friendly waste collection system.

The *polluter pays* principle is the basis, together with the integrated pollution prevention and control (IPPC) principle, for the introduction of *producer responsibility* for the waste management of a range of defined products. Packaging was one of the first areas where producer responsibility was introduced (1994). Electronic and electrical equipment, batteries and end-of-life vehicles are also subject to producer responsibility in some countries. This implies that the producers, often through their organization or as members of an organization specifically set up for managing the producer responsibility, pays for the waste management induced by the product. The specific products do not necessarily have to be managed in a specific waste management system, but the producer can pay a fraction of the cost of the existing waste management system corresponding to the contribution caused by the products. In Germany, packaging is collected in a separate waste management system (called *Duales System Deutschland* or 'the green dot system'), while producers in France pay the public waste management system for taking care of packaging waste as a fraction of the municipal waste. Producer responsibility may also have to meet specific goals, for example as to the recycling of the material.

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