Chapter 11

Closing the Loop – Disposal, Re-use, Recycling, and the Environment

In the packaging cycle that provides the framework for this book, the continuing path of the materials used in packaging after its first use lies within the consumers' decision to discard, recycle, or re-use the package, as shown in Figure 11.1.

Industrially developed countries have considered disposal of smaller containers as a traditional solution, although recycling is becoming more popular because of a combination of motivating factors that will be discussed in this chapter. Many ancient cultures and those in developing countries often re-use packages and transportation containers whenever possible because of the difficulty and expense of replacing them – a viewpoint that finds renewed relevance as manufacturers begin to consider not only the entire life cycle of the product, but the continued sustainability of their operations in a more global perspective.

The decision that the consumer makes is a complex one, touching on both pragmatic economic and technical realities and more idealistic social goals, although many times they are not aware of the process at the time. Similarly, setting societal expectations in the form of regulations, economic incentives, and social awareness is a complex problem that requires a broad understanding of the materials, economics, and public perceptions involved. Some of these factors will be discussed in this chapter, although this is by no means a complete treatment of the factors involved.

Bottles and other types of beverage containers have had some success in re-use either because of their design for re-use, ease of cleaning, and legislation requiring beverage manufacturers to take back containers ("Bottle Bills"), or because beverage manufacturers find it economically viable to put a deposit on their containers so that they can re-use them. Some of the examples that are used for industrial and distribution packaging were discussed in Chapter 9.

Whereas this solution may work as an incentive for re-use of glass containers and some specialized plastic beverage containers, most plastic and metal containers must be taken backward several steps into "raw" materials for recycling of the basic material into newly fabricated containers. Most other packaging types fall into the recycling category as well, although there is a patchwork of legal requirements and many types of technical and economic complications involved in recycling packaging. The materials-recycling solution is also gaining in popularity for containers and materials that are more obviously not reusable, as well as other durable and non-durable goods. As the infrastructure for transportation, reclamation, reuse, and marketing of these materials increases, the viability of re-use of even larger quantities of materials grows as well. The combination of diminishing resources (with an attendant rise in prices), legislative changes, and the difficulty of disposal has been a strong motivator for industries from

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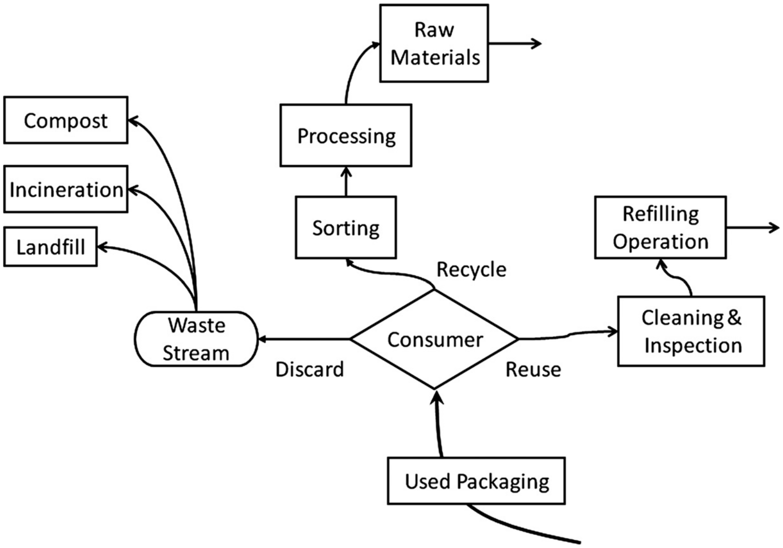

Figure 11.1. Flowchart of Materials after Package Use

automobile manufacturing to consumer electronics to begin to examine the complete life cycle of their products and the consideration of the sustainability of their operations. Finally, traditional disposal methods – dumping or burning – can no longer be seen as easy solutions because of public concerns with groundwater and air contamination, land use, and health effects. It is no longer possible to simply dig a hole in the ground and fill it with any sort of garbage in most developed countries – the town dump has largely disappeared. In its place, large and technically complex (as well as expensive) landfill sites have sprung up to fill the need for disposal space. Similarly, incineration has grown in complexity from the "burning barrel" stage to large-scale operations fitted with pollution control equipment and often capable of operating as an electric-steam co-generation facility. In the end, then, packaging that makes up a large and very visible portion of the discarded materials produced in most civilized countries will take the path of least resistance, either for economic, regulatory, or social reasons, but the path that it takes may be quite complex.

Re-use of Containers

The re-use of many types of food containers is currently impractical and unmarketable in a mass-marketing society. For a variety of sanitation and esthetic reasons, few consumers would bring empty soup cans to a store or factory to be re-filled even if it were technically possible, even though a moderate percentage of sturdy containers such as glass jars and steel cans are re-used for other purposes around the home. Re-use of containers demands an entirely separate handling system for the return, cleaning, and refilling of containers. This limits their applicability to containers that can be designed for many trips through the use cycle before degrading to the point where they cannot be used again. "Bottle Bills" – involving mandatory fees paid on purchased containers that are refunded to the customer when the container is returned – currently exist in 23 states and provinces in North America and provide a framework where this sort of utilitarian re-use works. Glass beverage containers and specially fabricated plastic bottles in several operations in Europe have been designed for this type of durability, but other, less durable containers that are returned under Bottle Bill requirements – plastic soft-drink bottles and aluminum cans, as well as many types of glass containers that are not designed for re-use – are typically recycled for their material content.

To provide for a sustainable bottle return system, there must be economic incentives in place as well as public infrastructure to support it. In a typical Bottle Bill state, retailers must set aside space to return and store containers, and either provide space and utility connections for automated return devices or provide employees, facilities, and space to accept and store returned bottles. Additional requirements range from backhaul capacity for the empty containers to filling lines or recycling operations, and the ability to process the empty containers either by reducing them into scrap or washing and re-shipping them must be provided and maintained. The financial cost to producers is substantial, mostly in the capital investment in returnable containers that are often more costly than disposable ones, but washing and handling facilities have to be maintained. This cost is usually reflected in a higher per-unit price for beverage products in deposit states.

The political price is often high as well – container manufacturers who have invested in the production of large quantities of disposable containers will not want to lose the revenue that producing one returnable container instead of ten to twenty-five equivalent disposable containers will represent. The loss of jobs that this production changeover entails represents a political liability, unless a clear case for equivalent “green” employment can be made. This has had the result of making Bottle Bill legislation both very contentious and their opposition typically very well funded by retailers, bottlers, and container manufacturers.

Technical Aspects of Package Re-use

For food containers to be safely re-filled and re-used, they must be thoroughly cleaned, typically by a combination of water and alkali solution washes, and then inspected for physical defects. For plastic bottles to be re-used, they must also be inspected for the presence of residual contaminants that may have migrated into the plastics as a result of consumers using them for storage of non-food materials such as gasoline, waste motor oil, or insecticides. This has typically been done with frequency-specific infrared or near-infrared (NIR) sensors that are responsive to specific key wavelengths of typical contaminants. Because of the speeds required for such inspections, it is currently not possible to check for every possible contaminant, but those that are most likely (fuels, oils, household and gardening chemicals) are typical targets. Future implementations of these kinds of inspections may allow for a broader range of target spectra.

Containers used in re-fill systems are typically sturdily constructed and may have design features that mask the wear and tear on the container as it repeatedly travels through the filling and distribution system. Glass containers are typically quite robust and may be standardized to distribute inventory in a bottle pool among brewers or bottlers in a given region. Plastic containers, although less brittle than their glass counterparts, are typically much more prone to cosmetic damage from abrasion and must either be designed in such a fashion that the abrasions and scratches do not significantly detract from the container, or must accommodate the problem in some other fashion, such as a replaceable overwrap label.

Re-use of other containers

There is a vast assortment of re-usable containers for other types of packaging, particularly for distribution and non-consumer packaging such as aseptic IBC containers as have been previously described in Chapter 9. Most of these combine a sturdy, re-usable physical support with some kind of disposable sterile inner container (usually a multiwall bag). For non-sterile use, most production facilities use re-usable bins unless the cost of transporting the empty bin or container between the parts or ingredient manufacturer makes it impractical for economic reasons.

Recycling

Recycling at its simplest is the re-use of the materials in a package without using the intact package again. Typically, this is the result of the decomposition of the material back to an intermediate state (resin particles, wood fiber, glass shards, or metal fragments) and the subsequent reforming of the container from all or part of those materials. Some materials, typically highly cross-linked thermoset polymers such as car tires, will require decomposition back to a very basic chemical state in order to be reused as anything other than relatively inert filler materials. The costs and energy input for this can be considerable, with the result that many of these types of materials are being investigated as fuel rather than material sources, and the final economic outcome is often very changeable.

The implementation of this takes any number of different forms, as shown in Figures 11.2–11.4, ranging from the now-common recycled office paper to multilayer plastic containers that encapsulate the recycled content in a layer of virgin resin. The typical requirements for recycling involve separation of waste into material-specific components, reduction of volume, transportation, and either the incorporation of recycled material in the production of new material, such as incorporating recycled paper into the production of "new" rolls of paper, or reforming the material so that it can be used in the production of new items such as recycled plastic resins that may have been pelletized in an extruder.

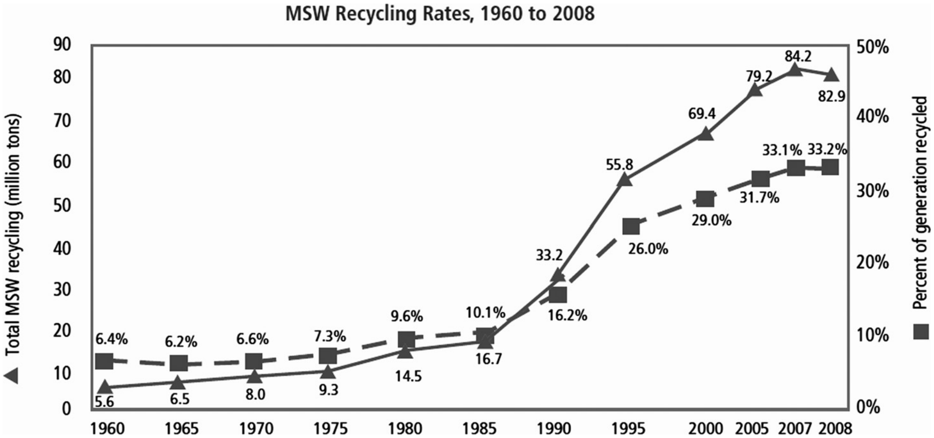

Figure 11.2. US Recycling Rates
Source: EPA

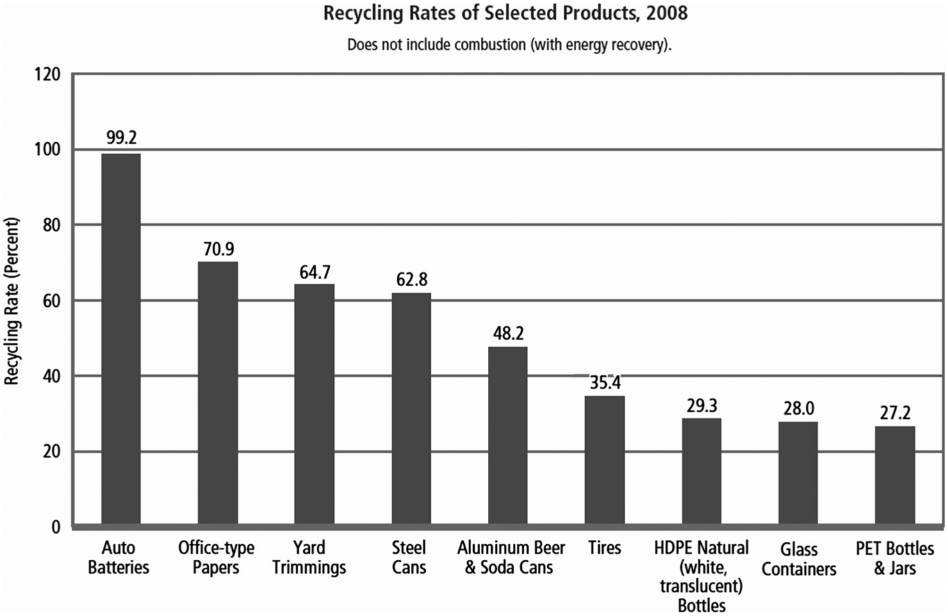

Figure 11.3. US Recycling Rates of Selected Products
Source: EPA

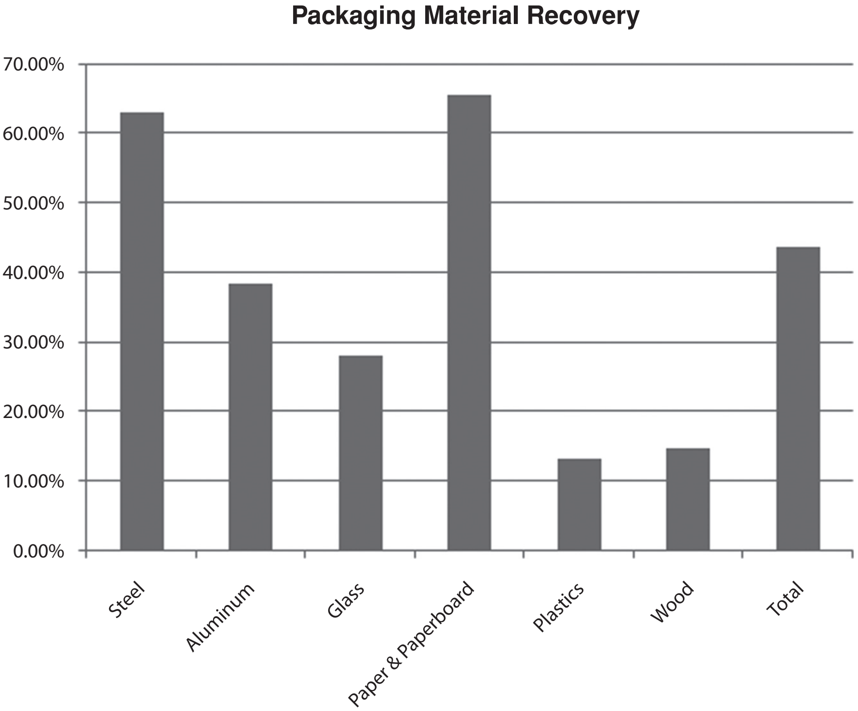

Figure 11.4. US Packaging Material Recovery Rates
Source: EPA

Recycling Segregation

Waste separation is often accomplished as a combination of efforts by the consumer, who may segregate waste to a certain extent by separation operations – both manual and automatic – at a primary receiving or transfer station, and by the final recycling operation such as a steel mill or plastic pelletizing facility. The extent of pre-sorting and separation will be a function of the community's size and the facilities and markets for recycled materials that are available to it. Large, crowded communities near economically viable materials-recycling operations may have a more complex sorting policy and operations than a small rural community that may seek only to remove a certain specific types of materials. In general, systems operate as single-stream (complete mixture), dual-stream (usually fibers such as paper, and glass, plastic aluminum and steel containers), and multistream (requiring a high degree of consumer presorting).

Much as landfills have moved to larger, more efficient operations, the trend in recycling separation has begun to move to larger, more automated separation that can allow the recycling operation to go to a more mixed material stream. Some of the separation technologies include the following.

Airflow Separation

Airflow systems separate materials by density, usually allowing glass to fall to the bottom of the sorting process and removing paper and aluminum in the airstream.

Star Screens

Star screens are conveyor systems that use rotating star-shaped cogs to transport material from one end to the other by pushing it along from underneath. Small material fragments fall out between the cogs and between the fingers while larger material is transported through to the other side.

Trommel Screens

Drum-shaped screens that rotate around the direction of material flow, sifting smaller pieces of material out through the grating as they move along and are tumbled. This can be combined with a magnetic separation system that pulls ferrous materials from the tumbling waste.

Eddy Current Separator

Current-flow devices that induce a counteracting magnetic field in electrically conductive materials by providing a high magnetic flux density using spinning magnets or applied alternating electric fields, then catching the materials as it is levitated off the end of a moving conveyor. Because most non-magnetic metals such as aluminum and stainless steel are sufficiently conductive, eddy current separators are typically implemented after ferrous, magnetic materials are removed by standard magnets.

Plastics Separation

This is often done by hand, but there are a number of different automated separation systems, most based on some aspect of the polymer's response to light or X-rays. Light-based separation develops sorting criteria from NIR and visible light to ascertain color and, in the case of

NIR, composition. Newer systems combine NIR and visible sensors into a single module to provide both polymer identification and color separation. X-ray systems are based on absorption or Energy Dispersive X-Ray Fluorescence and by targeting specific responses to distinguish material types.

Volume Reduction

Volume reduction can take many forms, depending on the type of material involved, the amount of transport necessary, and the markets for the particular materials. Metals can be crushed, with larger items such as automobiles and appliances crushed or shredded, paper is typically compacted and baled, glass is sorted for color and crushed, and plastic is usually compacted or shredded before any shipping occurs.

Recycled Materials Processing

Steel and other ferrous metals are typically recycled in an electric arc furnace as described in Chapter 3, and incorporate ferrous scrap of all types, from packaging to vehicles and structural steels. This recycled steel is then treated as any other steel source and is then used to fabricate new items of all types depending on the quality of the final product, including structural building components. Recycled materials have begun to be a requirement of new building construction, particularly with government buildings [1] and those projects that wish to qualify as a “green building” [2].

Aluminum is recycled in similar fashion, with empty containers baled and shipped to a recycling furnace operation. From there, the cans are shredded and burned free of organic decorations and labeling in a dedicated furnace and re-melted along with salt and potassium fluoride to assist in the removal of oxides, then cast into ingots or billets for rolling or extrusion. Recent furnace designs have also incorporated energy recovery from the coatings and decoration residue [3]. There is an ongoing concern with the quality of scrap aluminum that is returned for recycling, both in terms of moisture content that can cause separation problems, and heavy metals that might be incorporated into the food contact surface of a can [4]. Recycled aluminum requires only a fraction of the energy to be re-cast when compared to converting raw ore (10 MJ/kg versus 220 MJ/kg), so the economic incentive has been enormous (and is increasing with the increase of energy costs), and aluminum has enjoyed a high recycling rate for some time.

The incorporation of recycled material in glass production is simply an extension of the traditional re-use of pre-consumer cullet that is the result of breakage and other waste in the glass manufacturing process. Recycled glass is typically sorted for color, either by hand or with the aid of particle imaging sorters, and fed to the charge of the glass furnace.

Recycled paper fiber is incorporated at the vat stage, and usually must face some separation processing to remove adhesives and other contaminants (including an increasing number of electronic devices such as anti-theft and RFID tags). Separation is usually accomplished by reducing the recycled paper to pulp and then subjecting it to several stages of cleaning in order to remove large, dense contaminants such as staples, and then using screening and hydrocyclones to remove less dense contaminants such as adhesives, tape fragments, and waxes. The presence of these lighter contaminants is an ongoing concern for the paper industry because they will clog screens and slow paper output, though presorting and the separation processes have managed to control defects.

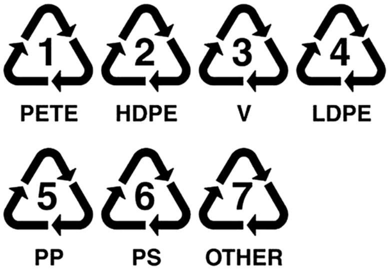

Figure 11.5. Plastic Recycling Symbols

Plastics are typically sorted for content according to the recycled material label incorporated into most plastic moldings (Figure 11.5) and will usually be separated, finely shredded, pelletized, and even depolymerized then repolymerized for use in extrusion and molding equipment.

One of the ongoing challenges for recycled polymers, and particularly PET from drink containers, is that there is concern about contamination from materials either included in the waste stream and not removed by cleaning, or materials sorbed into the polymer structure and desorbed from the surface of the new container. Depolymerization will overcome many of these problems, and in other cases, manufacturers have constructed multiwall containers that incorporate virgin PET resin as the food contact layer and recycled resin either as an encapsulated or outer layer. Currently, the United States approves the use of recycled content on a case-by-case basis through the Food and Drug Administration, which issues “No Objection Letters” for processes that can be regarded as not exposing consumers to hazards above the threshold of regulation (TOR) as described in Chapter 10. Work has been conducted to model and validate recycling processes to accommodate a modest amount of contaminants based on the idea that they will be diluted and encapsulated in the finished product, and will not desorb enough material to constitute a health hazard [5]. Considering that both plastic and recycled plastic content are somewhat controversial among some food consumers, this is likely to be an item of debate for some time.

Composite materials provide an ongoing challenge; paper laminated to foil and plastic film does not have a distinct material type to use, and this has been an ongoing criticism of the materials used in structures such as aseptic packaging and MRE military rations. The obvious solution is to incinerate the materials to recover the energy content, but this option is not always possible, so these materials often wind up in landfills. The conflict between composite materials’ difficulty of recyclability and the advantages offered by these types of materials structures has caused some conflict in the implementation of some types of packaging in certain markets, because many of these containers require less energy and material than more traditional structures. The preferred method for “recycling” of these laminate structures is given as pulping the cartons to recover the paper fiber, although no description of the fate of the foil or polymer layers is given, and one must assume that it is disposed as waste either by landfill or incineration [6].

Recycling Regulations

Recycling regulations in the United States have been a patchwork of local and state requirements that are not unified, nor is there a national standard for recycling requirements, although many of the existing regulations have been pushed into a de facto standard to consider the most stringent case and then producing to that standard. In other countries, recycling exists in a wide range of forms ranging from materials purchased from garbage pickers in huge municipal dumps to the attempts of the EEU to begin to standardize recycling as discussed elsewhere in this chapter.

Disposal and Landfills

"We're Running Out of Landfill Space!!" This was a complaint that was recorded in 1889 and probably dates back to the time of the first cities, as waste disposal is always a problem where people congregate [7]. This is currently something of an overstatement; in fact, developed countries are not running out of landfill space, but the days of simple and inexpensive garbage dumps are largely over in many developed countries because of the intersection of many social, environmental, and legal demands. Fortunately, modern cities do not usually have to deal with some of the disposal problems of older ones – thousands of tons of manure and many dead draft animals every day. According to industry sources, American states have future capacities ranging from less than 5 to more than 20 years, with states on the East Coast facing the most immediate shortfalls [8]. All states with the exception of Hawaii ship municipal solid waste (MSW) across state lines, which adds to both the cost and complexity of waste disposal, particularly in an era of inflating fuel costs. The longer-term implications of this are that areas with large tracts of unpopulated land or disadvantaged communities may develop economies around the operation of landfill or waste-handling operations disposing of material from other states. This is already occurring to a limited extent and can only increase along with the attendant public concern over economic, health, and safety issues.

Waste Production in the United States

Waste production in the United States is made up of five major components, and packaging makes up the largest (and most visible) percentage of those (Figure 11.6).

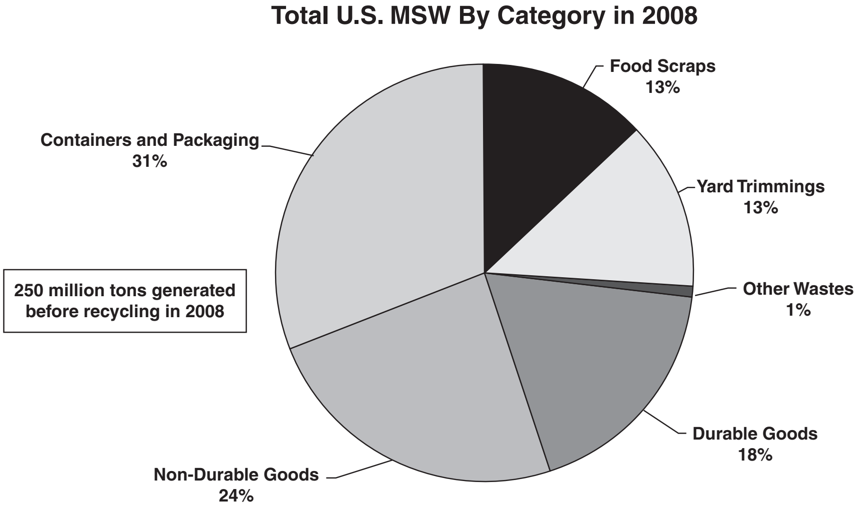

Figure 11.6. Municipal Solid Waste Categories
Source: EPA

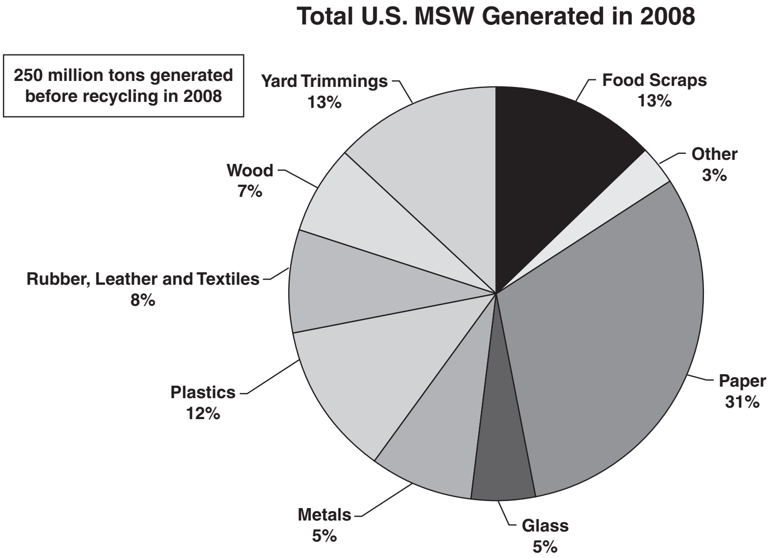

Figure 11.7. Municipal Solid Waste Materials Content
Source: EPA

What is less well understood by the general public is that the rest of the waste stream is also composed of:

Durable and Non-durable Goods

Durable and non-durable goods having a service life of three years or more for the former – usually items such as refrigerators and automobiles, and consumables that have a service life of less than three years for the latter.

Yard Waste

Yard waste that is increasingly either prohibited from municipal garbage collection or diverted into composting operations.

Food Scraps

Food scraps that generally represent a small percentage of the overall MSW stream and may be composted, although this is less common than with yard waste.

Central food processing facilities generally have an economic incentive to both use as much of the raw product as possible and to process their own waste to minimize tipping or sewage fees. Developing countries may have a very different composition of municipal waste, most notably with regard to food waste, because these countries use fewer centrally processed foods and discard the waste, both in trimmings and spoiled foods, directly into the municipal landfill, and may have fewer durable and non-durable goods to dispose of [9].

Landfill Construction

Historically, it was acceptable to simply let waste pile up, or dig a hole in the ground and push in any kind of discarded materials without regard for the consequences of materials leaching

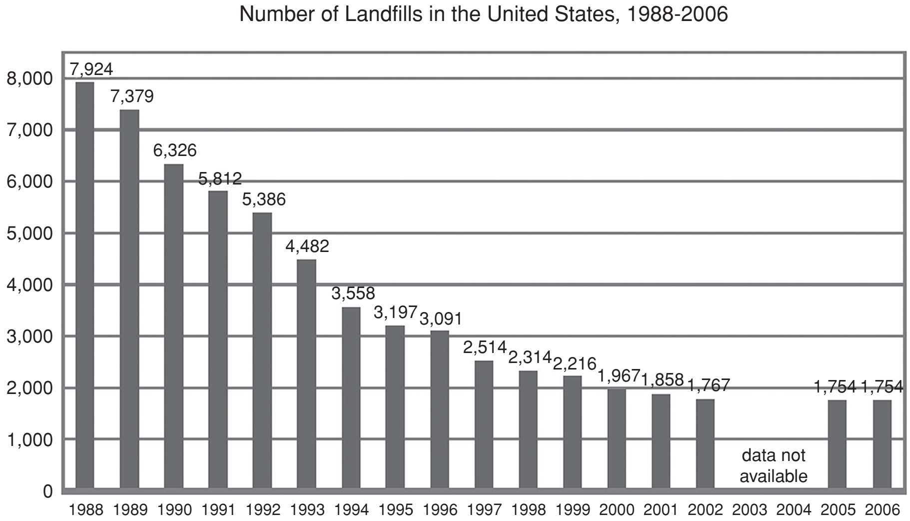

Figure 11.8. US Landfills in Operation
Source: EPA

into the soil or groundwater. The discovery of groundwater contamination by a vast range of pollutants contained in landfills, as well as changes in people's willingness to have disposal sites in their vicinity, has changed the legal, social, and economic framework of garbage. There will not be a shortage of landfill sites nationally, but the days of conveniently located and inexpensive disposal of materials are over, as shown in Figure 11.8, which is one of the motivating factors in many recycling schemes.

Currently, new landfills must be designed to minimize or eliminate groundwater contamination, because any rainwater that percolates through the accumulated garbage will extract many components from the MSW contained in the landfill and transport them into the groundwater supply. These can include lead and cadmium from batteries, pesticides and cleaning agents, and solvents and components used in paints, petrochemicals, and household chemicals. Sites based on industrial activities, such as chemical refining and munitions fabrication, have faced similar concerns. Constructing a landfill that will protect the groundwater supply usually requires building a clay and geotextile liner structure under the fill site, providing drainage and monitoring wells as well as gas vents, and carefully filling and monitoring the site to ensure that it is not contaminating the surrounding environment (Figure 11.9).

A longer-term problem is that materials are never lost from landfill sites. Because the materials are usually deeply buried, there is little air available for aerobic digestion of waste materials, and because there is little water available, efficient anaerobic decomposition of organic materials does not occur either. Archaeologists who explore modern landfills find food materials that are still recognizable (if not edible) after half-a-century [10]. The result of this is that, in effect, modern landfills are sarcophagi for our municipal waste, preserving it forever. Although some energy recovery is done via the promotion of biogas generation in the landfill, and this may be used to fire boilers or operate motor vehicles and specially constructed diesel-electric generators, material recovery costs are still too high to re-open landfills to mine the raw materials that they contain. Most communities in the United States are involved in some form of pre-separation and segregation of solid waste – compostable garden waste is almost

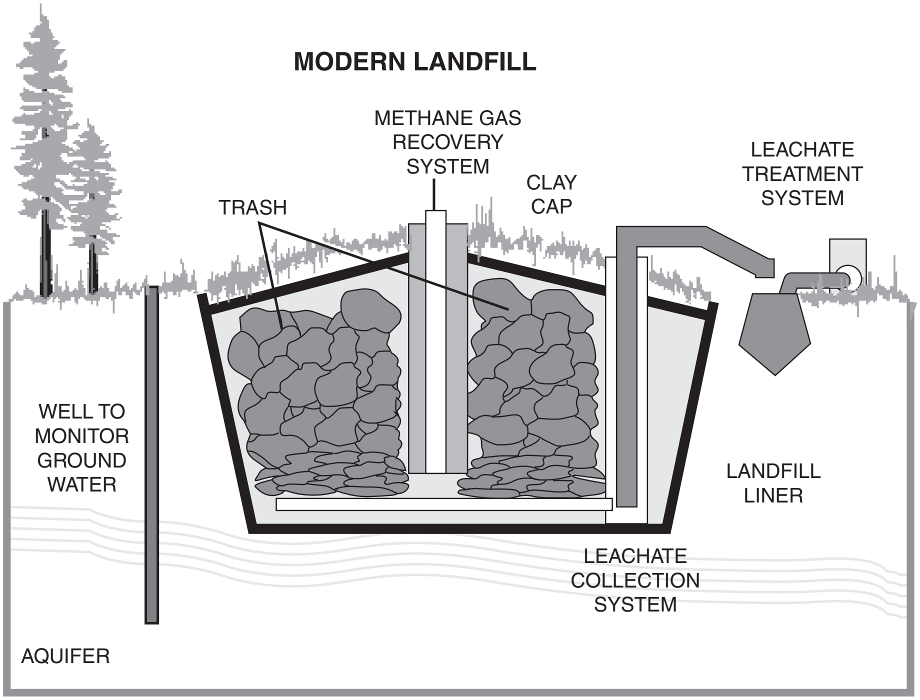

Figure 11.9. Landfill Cross-Section
Source: EPA

universally excluded from landfills – but post-landfill operations are virtually non-existent. In Europe, where both fuel and landfill costs are very high, biogas as a means of energy recovery is receiving a great deal of scrutiny [11]. Current regulations require substantial protection against groundwater contamination by leachate, but nine states are currently studying the operation of properly constructed facilities as "bioreactor landfills" that inject water to accelerate anaerobic decomposition to reduce volume and produce methane as fuel from organic content. An added bonus to the water-injection bioreactor landfill method is that landfill post-closure care is reduced significantly, reducing overall operating expense.

The end result of this combination of factors is that disposal costs for municipal solid waste have grown tremendously, and the availability of convenient disposal sites has been curtailed sharply because of the high cost of constructing and maintaining a properly operated solid waste facility. *Tipping fees* – the fees charged to dump materials in landfills – have increased dramatically and represent an important factor in the overall economic equation that motivates recycling in many areas (Figure 11.10). Items eliminated from the waste stream and recycled for their materials become one less cost that is incurred in disposal irrespective of their value, and may represent a significant factor in determining whether recycling is economically viable in any particular area.

Other Disposal Methods

These have been the occasional subject of public debacles over the years: garbage barges that are not allowed to offload in any port, or loads of toxic wastes that are shipped to developing

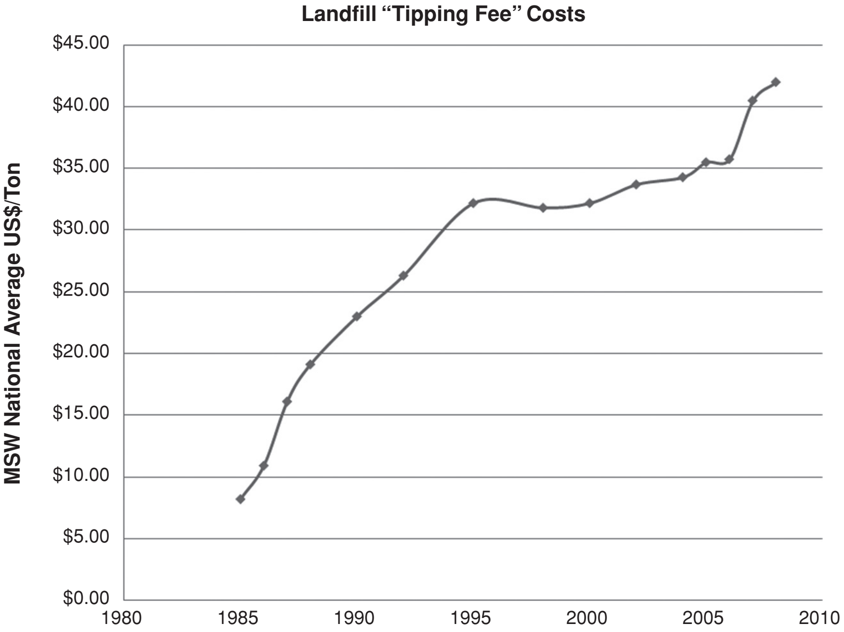

Figure 11.10. Tipping Fee Costs
Source: Generated from National Solid Waste Management Association data

countries to be handled badly, stored in inadequate facilities, or simply dumped among the local population [12, 13]. As global economic development accelerates the production of toxic materials, and rapid communication and disclosure of unacceptable disposal situations accelerates, these problems will become more visible and must be dealt with in a more proactive fashion. Typically, illegal disposal results from poor oversight, a lack of convenient or economic disposal alternatives, or simply a lack of concern beyond the immediate situation. The Basel Convention, first convened in 1989 as a response to improper waste shipments, and continued as an ongoing set of working groups and conventions, has sought to establish global protocols for cross-border waste handling among its 170 signatories, although lax local enforcement may make many of these moot [14].

Packaging Waste Programs Outside the United States

European Directives on Packaging and Packaging Waste

The European Parliament and Council Directive (1994/62/EC, of 20 December 1994, finally codified as Directive 2006/12/EC) on packaging and packaging waste demands that member states comply with the following directives [15]:

- By no later than June 30, 2001, between 50% and 65% by weight of packaging waste to be recovered or incinerated at waste incineration plants with energy recovery;
- By no later than December 31, 2008, at least 60% by weight of packaging waste to be recovered or incinerated at waste incineration plants with energy recovery;

- By no later than June 30, 2001, between 25% and 45% by weight of the totality of packaging materials contained in packaging waste to be recycled (with a minimum of 15% by weight for each packaging material);
- By no later than December 31, 2008, between 55% and 80% by weight of packaging waste to be recycled;
- No later than December 31, 2008, the following targets for materials contained in packaging waste must be attained: 60% by weight for glass, paper, and board; 50% by weight for metals; 22.5% by weight for plastics; and 15% by weight for wood.

Additionally, there are targets for heavy metals (specifically lead, mercury, cadmium, and hexavalant chromium) incorporated into packaging to be reduced over a five-year period (with the exception of leaded crystal).

In addition to this, there is a vast range of country-specific listings within the regulation that attempt to make accommodation for the member countries' different approaches to achieving these targets, including energy recovery via incineration. The European Parliament and Council are to have set further recycling targets for 2009–2014 as well. Portugal, Ireland, and Greece (the so-called P.I.G. countries) will get special dispensation because of rural, island, and isolated areas and do not have to comply with the targets until 2011, and new member states (Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungry, Malta, Poland, Slovenia, and Slovakia) have extensions until the end of 2012. There is often a good deal of disagreement among the member countries, because their requirements may have different wording or different standards. The current trend is toward reconciliation of these differences in order to further the growth of pan-European markets for recycled materials and products [16].

The actual implementation of this is somewhat more complex, with each of the member countries having its own standards for compliance and reporting, and there is a vast regulatory literature that exists in both the EEU and each country for this. It is illustrative to reproduce Annex II of document 31994L0062**,** The European Parliament and Council Directive on packaging and packaging waste as it gives the most useful definitions and impression of the legislative intent for the production of recoverable, non-toxic packaging:

ANNEX II

ESSENTIAL REQUIREMENTS ON THE COMPOSITION AND THE REUSABLE AND RECOVERABLE, INCLUDING RECYCLABLE, NATURE OF PACKAGING

1. *Requirements specific to the manufacturing and composition of packaging – Packaging shall be so manufactured that the packaging volume and weight be limited to the minimum adequate amount to maintain the necessary level of safety, hygiene and acceptance for the packed product and for the consumer.*
   - *Packaging shall be designed, produced and commercialized in such a way as to permit its reuse or recovery, including recycling, and to minimize its impact on the environment when packaging waste or residues from packaging waste management operations are disposed of.*
   - *Packaging shall be so manufactured that the presence of noxious and other hazardous substances and materials as constituents of the packaging material or of any of the packaging components is minimized with regard to their presence in emissions, ash or leachate when packaging or residues from management operations or packaging waste are incinerated or landfilled.*

2. *Requirements specific to the reusable nature of packaging. The following requirements must be simultaneously satisfied:*
   - *the physical properties and characteristics of the packaging shall enable a number of trips or rotations in normally predictable conditions of use,*
   - *(The) possibility of processing the used packaging in order to meet health and safety requirements for the workforce,*
   - *(Must) fulfill the requirements specific to recoverable packaging when the packaging is no longer reused and thus becomes waste.*
3. *Requirements specific to the recoverable nature of packaging*
   - (a) *Packaging recoverable in the form of material recycling Packaging must be manufactured in such a way as to enable the recycling of a certain percentage by weight of the materials used into the manufacture of marketable products, in compliance with current standards in the Community. The establishment of this percentage may vary, depending on the type of material of which the packaging is composed.*
   - (b) *Packaging recoverable in the form of energy recovery Packaging waste processed for the purpose of energy recovery shall have a minimum inferior calorific value to allow optimization of energy recovery.*
   - (c) *Packaging recoverable in the form of composting Packaging waste processed for the purpose of composting shall be of such a biodegradable nature that it should not hinder the separate collection and the composting process or activity into which it is introduced.*
   - (d) *Biodegradable packaging. Biodegradable packaging waste shall be of such a nature that it is capable of undergoing physical, chemical, thermal or biological decomposition such that most of the finished compost ultimately decomposes into carbon dioxide, biomass and water* [17].

The German Green Dot System

German Green Dot regulation was a groundbreaking innovation in recycling, both in terms of regulation and economics, and has been used as a loose example by many other countries including most of Europe, Croatia, Turkey, the United Kingdom, Canada, and Iceland. More interestingly, it has urged American packaging manufacturers, who have been averse to recycling legislation, into voluntarily adopting a modest level of recycling content into their own packaging, although this is also influenced by state ordinances, public goodwill, and materials cost savings. The Packaging Ordinance of 1991, last amended in 1998, obliges manufacturers and retailers to take back and recycle packaging, and establishes the basis for deposits on nonreturnable bottles. The nonprofit company, Duales System Deutschland (DSD), was established in 1991 to handle fees and logistics to help industry meet this requirement. DSD does not handle waste itself, but contracts local companies to collect and sort packaging materials, and pays for these services by a small surcharge on each item displaying the Green Dot (Gruener Punkt), which indicates that it is allowed to be handled by the DSD-compliant system. Because manufacturers and retailers are responsible for the return and recycling of packaging regardless of whether they belong to the DSD system or not, the complexity and expense of setting up one's own individual system is a powerful incentive to join the DSD system. DSD has been successful because of customers' presorting of materials, and helped propel Germany to an astonishing recycling rate of 77% for all packaging and a reduction of packaging by 20% between 1991 and 2002. Although the results for the DSD scheme have been remarkable, there has been criticism in the European Commission as well as with German regulators of its near-monopoly position, and alternative collection methods are now more easily permitted [18]. DSD has also restructured its advisory board to exclude waste management firms and is examining energy recovery consistent with the goals of recycling 36% of plastic packages [19].

Canada

Recycling and disposal in Canada is distributed among several government agencies and is largely left to the individual provinces and territories and their municipalities to construct and administer. Canada has recycling and return systems as previously noted, and a strong set of programs for the administration of internal and external cross-border waste movement, particularly with regard to the Basel Convention, but has left more local concerns for municipalities to deal with. The Federation of Canadian Muncipalities (FCM), similar to the CONEG group in the United States, is a consortium of Canadian cities that confer to share information and establish and document reasonable requirements for waste management and recycling [20]. Because of the relatively sparse population in the region's northern provinces, and broad geographic diversity, the waste and recycling requirements will vary widely, but the national exchange has promoted a high rate of beverage container capture within Canada, as well as a strong recycling and prohibited content system in all provinces and territories except Nunavit (which has a population density of fewer than one person per 66 km^2).

Japan

Japan, with its scarcity of natural resources as well as space for landfills – it has only 1.5 years left for industrial landfills and 11 years for municipal sites – has created one of the most meticulously detailed recycling plans of any country [21]. Municipal solid waste is separated into burnable and non-burnable categories, and recyclable sub-categories such as metal and glass, with larger items such as appliances handled separately. Cities in Japan may issue further directives to specifically sort particular items into distinct categories, with the large city of Yokohama having 10 and the small village of Kamikatsu (which seeks to completely eliminate garbage by 2020) having 44 distinct categories of recycling to be sorted. The results have been instructive in that the increased sorting has decreased the amount of material going to incineration (which handles approximately 80% of Japan's waste) at approximately the same cost [22]. Japan enacted the Containers and Packaging Recycling Law in 1995 that requires businesses to recycle their containers, but designates the Japan Containers and Packaging Recycling Association as a recycling-fee handling organization that allows manufacturers to pay fees and have the recycling handled by third parties, much like the German DSD system. In spite of this, Japan has a relatively low recycling rate of approximately 16% of its total MSW, although this is balanced by the relatively low per-capita production of waste (410 kg/year/person for Japanese versus 740kg/person/year for Americans). Japan is also the first country to enact legislation – the Home Appliance Recycling Law – requiring producers of durable goods (specifically air conditioners, refrigerators, washing machines [and presumably dryers] and televisions). The fees for this are borne by consumers who pay for the return of used appliances, as well as additional collection and recycling fees at the time of purchase [23].

Developing Countries

In general, public waste collection and recycling is much less formal in developing economies. Lack of understanding of waste volume and composition and lack of consideration of environmental impact of improper disposal work together with inadequate and poorly organized landfills and recycling programs to produce an inefficient (and often corrupt) disposal and recycling systems [24]. Although it is tempting to regard these problems as something confined to developing countries, the continued presence of scandals surrounding the waste management practices of developed countries, as well as the urban equivalent of garbage pickers – ragpickers, kabaris, and pepenadores – in some of the most affluent cities on Earth, remind us that it is just a matter of degree.

An optimistic view, based on experience, is that as economies develop, and standards of living increase, there is usually an increased demand for some type of remediation of hazardous municipal and industrial waste. This occasionally leads to social unrest, such as the protests against industrial pollution in Dongyang, China, in 2005 [25]. The final results of these are often mixed, but usually result in some improvement of waste handling practice and thus better protection of the population and environment.

India

Although projects for incinerators and gasification systems are underway, India's municipal recycling efforts often lie, literally, in the hands of *kabaris*, who broker waste from garbage pickers who extract materials from dumps under hazardous conditions. Although efforts have been made to curtail the practice, recovery from large dumps and trash bins is often done manually [26]. Larger quantities of materials, such as industrial recycling of scrap, may find a more direct market, and hazardous waste has been shipped from India to the United States for re-processing as a result of vocal environmental concerns [27].

People's Republic of China

China's economy has grown so explosively that the need for basic resources and materials has driven the import of recycled and discarded material, typically as "backhaul" in otherwise unused shipping containers that have been used to export manufactured goods. Basic materials such as copper are extracted from used wire, and recycled plastic containers are being imported from landfills in the United States amidst controversy that the materials are simply being dumped in China. This claim is disproven to some extent by examining the market for used materials in China – ads for scrap plastic and other materials are common. Paper is recycled in backhaul shipments as well; Nine Dragons Paper Holdings has become one of the world's largest producers of paper on the strength of its ability to return paper and packaging from goods exported to the United States and re-process it into paper for a dynamic Chinese economy [28]. Other locally discarded materials are returned in a system similar to that of India, often by small entrepreneurs who pay ragpickers for small quantities of product. Other types of recycling have flourished as well, reprocessing electronics and other goods from the United States and elsewhere among substantial concerns about toxic working conditions and environmental impact. Overall, China suffers from the combination of enormous growth, often underwritten by foreign investment, little or no effective regulation, and the inevitable results of having the regulatory bodies and agencies being the primary investors and shareholders in many of the polluting companies.

Taiwan (Republic of China)

Although Taiwan's economy is much more mature than that of The People's Republic of China, it is included with this segment as a contrast to the disposal and recycling practices in the P.R.O.C., because the populations and geographic regions are so similar, with differences being largely political and economic. Taiwan has had an ongoing series of regulations beginning with the (Solid) Waste Disposal Act in November, 1988 that promotes recycling as a resource-conservation measure rather than one of waste remediation. The Republic of China Environmental Agency (ROC EPA) has promoted a 17-point plan, the Hsi-Fu Recycling Project – Hsi-Fu refers to the sparing use of one's wealth or resources (this title was changed to Urban Waste Recovery and Monitoring Project in 1991 but the term is not generally used). In this system, either the customer or manufacturer (and occasionally both) bear the economic burden of materials with surcharges on various items. For some items such as tires, this is usually added at the time of purchase, whereas with aluminum cans, a surcharge is placed on the manufacturer and the consumer is not directly charged. Recovery, recycling, and re-use capacity is high, with many plants licensed to collect and reprocess waste.

Problems exist with separation processes as well as competition between domestic and imported goods and their fee structures, but Taiwan's efforts have been very good regionally.

Mexico

Mexico, with very little regulation over MSW systems, suffers from the results of increased consumption of consumer goods brought on by expanding economic affluence, population concentration in urban centers, and a lack of well-planned and regulated landfills. During the 1990s, significant gains were made in diverting the waste stream from open/illegal dumping and uncontrolled dumping to sanitary landfills, but recycling rates remain extremely low and often in the hands of *pepenadores*, who scavenge dumps for glass, metal, and PET bottles (if there is a market for them) [29, 30]. Some progress toward recycling has been made in the area of specific materials such as PET bottles, but the system struggles from a lack of investment and enforcement, as well as substantial barriers to properly managed disposal and recycling processes related to both economic level and habit [31].

Incineration

Although incineration can be a useful method of disposal, many communities do not want the possibility of exposure to toxic contaminants from the municipal waste stream. Conversely, some communities see these facilities as a source of economic development. Although it might be intuitively obvious that burning municipal solid waste is a good source of fuel for electrical generating plants, in fact, the variability of the materials contained in these waste streams, as well as changeable moisture levels and differing levels of toxic contaminants, make waste-fired power plants a difficult proposition. Department of Energy research projects have been focusing on the combination of municipal solid waste with coal and limestone to produce a high-efficiency power plant that produces very low levels of emissions.

Incineration beyond the backyard burning barrel presents both an ongoing challenge for waste disposal and a convenient method of reclaiming some of the energy content of packaging materials. Because of the mixed nature of the municipal waste stream, the raw material going into the incinerator may contain toxic materials (most notably, thermally stable metallic toxins such as lead, mercury, and cadmium) as well as other hazardous materials such as polychlorinated compounds and even direct biohazards, although high incineration temperatures tend to make these organisms more of a problem of perception than an actual hazard in a properly operated system [32, 33]. These hazardous materials are seen as a risk both from gaseous dispersion in the flue gasses and from the ash that may be dispersed with the flue gasses or must be disposed of in landfills and may leach toxins into the groundwater [34]. Several ingenious schemes for incorporating non-hazardous incinerator ash and other solid waste as building materials such as drywall, as road building materials, and other re-use schemes that render the materials somewhat inert are under evaluation [35]. Under current regulations, ash is required to be sampled and analyzed regularly, and ash that is determined to be hazardous must be managed and disposed of as hazardous waste.

Public reaction to the construction of incinerators often falls into one of two arenas: one concerned about the environmental or other negative effects, and the other concerned with the income or other benefits that may accrue from locating the incinerator in the community. Not surprisingly, these tend to segregate along economic lines, with further debate occurring around the ethics of targeting low-income urban and depressed rural areas as potential incinerator sites.

Electric power generation, recovering a good deal of the energy content of the MSW stream, has been a facet of the incineration equation for some time. Initial problems with the heterogeneity of the feedstock and boiler operation have given way to efficient generation of electricity using both MSW gas production from landfills, mentioned elsewhere in this chapter, and direct incineration of MSW using moving-grate incinerators as the boiler heat source (Table 11.1).

Additionally, diesel-generating equipment manufacturers have overcome some of the initial difficulties encountered with operation on impure methane, and they are now producing durable

Table 11.1. Heat of Combustion of Biomass Fuels

Average Heat Content of Selected Biomass Fuels		
Fuel Type	Heat Content	Units
Agricultural By-products	8.248	Million Btu/Short Ton
Black Liquor	11.758	Million Btu/Short Ton
Digester Gas	0.619	Million Btu/Thousand Cubic Feet
Landfill Gas	0.49	Million Btu/Thousand Cubic Feet
Methane	0.841	Million Btu/Thousand Cubic Feet
Municipal Solid Waste	9.945	Million Btu/Short Ton
Paper Pellets	13.029	Million Btu/Short Ton
Peat	8	Million Btu/Short Ton
Railroad Ties	12.618	Million Btu/Short Ton
Sludge Waste	7.512	Million Btu/Short Ton
Sludge Wood	10.071	Million Btu/Short Ton
Solid By-products	25.83	Million Btu/Short Ton
Spent Sulfite Liquor	12.72	Million Btu/Short Ton
Tires	26.865	Million Btu/Short Ton
Utility Poles	12.5	Million Btu/Short Ton
Waste Alcohol	3.8	Million Btu/Barrel
Wood/Wood Waste	9.961	Million Btu/Short Ton

Source: Energy Information Administration, Form EIA-860B (1999), "Annual Electric Generator Report – Nonutility 1999."
http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table10.pdf

Table 11.2. US Energy Production from Municipal Solid Waste

Source	2005
Municipal Solid Waste	299×10^{12} Btu
Landfill Gas	148×10^{12} Btu
Other Biomass	130×10^{12} Btu
Total Heat Generation	577×10^{12} Btu
Electrical Generation from MSW and landfill gas*	20×10^{9} kWh

*Note that the electrical generation is included in the preceding Btu figures – much of the heat energy produced from MSW and landfill gas is used for electrical generation.
Source: Energy Information Administration http://www.eia.doe.gov/cneaf/solar.renewables/page/mswaste/msw.html

equipment for direct on-site generation of electrical power at landfills. Microturbine and fuel cell generating facilities are being evaluated for use with both landfill gas and sludge digestion in sewage plants. Both MSW direct incineration and landfill gas in the United States produce an estimated 577 trillion Btu of total energy (Table 11.2), including 20.0×10^9 kWh of electrical energy generation as well as a limited amount of fuel for vehicle operations, typically LNG/CNG-converted vehicles used in the landfill as well as a limited amount of sales to the public [36].

Composting

Composting represents a useful way of recycling easily biodegradable organic materials into fertile humus material that is most often re-used in agricultural operations or redistributed for home, commercial, and highway landscaping and gardening use. Because of its applicability both for packaging systems and food-processing waste, the material here is somewhat more extensive than some of the other sections in this chapter. Composting can be used for many types of materials and is most often used to deal with the lawn and garden and other organic waste components of municipal waste streams, often termed *Source Separated Organics* (SSO). Other sources of compostable materials are from food processing facilities and a limited range of packaging materials, most usually paper- and bioplastics-related.

The economic impetus for composting is persuasive – in the Everett, Washington-based Cedar Grove composting facility, tipping fees are approximately \$25/ton versus landfill costs of \$115/ton. This cost differential, as well as an operating facility that has cleared the hurdles for environmental impact, attracts compostable materials from Portland, Oregon – more than 325 km away [37, 38].

Although composting generally refers to nearly any kind of decomposing plant or animal matter, in most commercial applications it refers to operations that depend on lower-odor aerobic digestion, which in turn depends on the previously mentioned co-factors as well as a proper carbon-nitrogen ratio to provide the necessary decomposition and lack of ammonia formation. Commercial composting facilities typically will have the capacity to aerate the decomposing biomass as well as adding necessary water to promote aerobic microbial proliferation.

Compost Processing Methods

Windrows, forming long piles or heaps of SSO material in open areas, are a common and initially inexpensive method of managing composting where sufficient land is available. Aeration usually depends on a mechanical windrow turner. These can range from small, simple devices usually attached to a front loader or tractor that is used to form the windrows, to larger, self-trailering machines. The turner will churn the material in the compost windrow to allow proper aeration of the material and therefore assist in odor control. Organic material that is too dense to promote rapid aerobic digestion may be mixed with wood chips or other material to promote better air circulation. Water may be added with sprinkler systems or naturally occurring rainfall may suffice. Although this method is relatively simple, it requires a large land area and often a high operating cost because of the necessity for turning-vehicle operation.

Biologically, composting goes through three stages:

1. Consolidation, when SSO materials are mixed with water and bulking agents such as wood chips, formed into a windrow, and the bulk density of the windrow is established;
2. Active, when the core temperature is maintained ideally between 50°C and 60°C and the breakdown of the SSO organic material begins.
3. Curing, when the core temperature drops and nutrients are released in the inorganic form. In a mature compost, microbes have converted the readily available organic matter into humic acids and microbial cells. Immature composts may have partially developed compounds that prove unsuitable for agricultural use.

Other composting methods of processing SSO materials can represent a larger initial investment but may prove to be more efficient in the longer term because of reduced processing costs. These include variations on the windrow method that can include forced aeration methods that reduce the necessity for turning machinery, enclosing the composted material in buildings or dedicated containers either for capture of odors or control of other environmental factors such as temperature or moisture content, or various sorts of in-vessel composting that allows control and transport of composting materials. Additionally, there are mechanical drum (*digester*) systems that agitate the compost and are typically used to combine materials and initiate compost digestion, with the exception of small household units that are not used for the complete composting cycle.

Composting Optimization

Compost digestion operates within an imprecise range of values for the critical factors affecting microbial conversion of SSO to low-odor compost; carbon-nitrogen ratios, moisture and oxygen availability, and temperature. Carbon-nitrogen ratios of approximately 30:1 provide the best ratio for operation, whereas too little nitrogen will result in undernourished microbial action and slow composting, and too much nitrogen will result in excessive ammonia and odor formation. Moisture is typically best maintained at approximately 35–40% of the total weight of the compost material for optimal microbial growth. Oxygen availability for the compost material is critical as well, and insufficient oxygen availability will result in anaerobic digestion of the compost material, which is much less efficient and will produce undesirable odors. Occasionally over-ventilation will occur, which may remove moisture from the compost and result in slower microbial action. Managing the combination of moisture, which tends to compact compost material and make it more difficult to aerate, and oxygen is an essential part of compost management. Temperature can be critical as well, as composting operates most efficiently at a relatively high temperature (50-60°C). Although this is self-regulating to some extent, exceedingly high temperatures can accelerate moisture loss, microbial species may be deprived of oxygen and moisture, and the system may self-sterilize, causing microbial action to cease prematurely. Low temperatures will slow microbial action and in severe climates may result in the cessation of microbial action altogether. Because there is a lot of biogenic heat produced in aerobic composting, insulation management in cold-weather operations may be sufficient for the process.

Odor Control

Although composting operations typically produce a low odor level if properly maintained and managed, the incoming feedstock (animal manure or food processing plant waste) or close proximity to urban areas may require additional steps to control odors. These may include the use of covered facilities with odor control machinery, dedicated composting vessels based on drums or steel shipping or waste containers, or the use of ventilation structures combined with selective permeability membranes that allow gaseous emissions to be vented while retaining the heavier organic compounds that then condense and are recycled back into the compost to be broken down further [39].

The Economics of Waste Handling

No matter which disposal or recycling method is considered, the basic laws of economics will eventually determine whether the system will be maintained. Generally, one can see the equation as a combination of factors, but each situation will have its own unique concerns, as shown in Table 11.3, often having to do with difficult-to-quantify social factors or future concerns, or costs that are often hard to predict. An efficient and environmentally sound disposal system can lead to a better disposition of materials, but the attendant increase in costs may also accelerate the removal of material into recycling or incineration schemes or even the improper dumping of materials.

Note that several of the methods for dealing with waste produce both revenue and a reduction of cost. For example, removing a plastic bottle from the waste stream not only returns the value

Table 11.3. Composting Costs and Revenue Sources

Revenues	Costs
Collection Fees	Labor
Recycled Material Sales	Transportation
Subsidies, direct and indirect (taxes, bottle deposits)	Tipping Fees
Reduced costs from waste diversion (composting, container reuse, recycling) and compaction (evaporation, mechanical compacting)	Facilities Costs (both landfill and intermediate transfer stations)
Composted materials sales	Requirements for specific material content in packaging
Energy generation and sales	Sales and distribution costs
Goodwill – community acceptance of waste handling method.	Capital investment in returnables and infrastructure

of the plastic in that bottle but will also incrementally reduce the amount – and therefore the cost – of material that must be interred in a landfill. Also, note that often the determining factor in a waste handling scheme, particularly for large, rural populations or for systems that ship waste over long distances, is the transportation cost. This is often a major factor in determining whether a smaller or more distant community can recycle all types of materials or only select ones that have enough value to make it worthwhile to transport them over long distances.

An additional problem arises when municipal waste is collected by private companies but recycling efforts are publicly funded. The expense of the programs is borne by the taxpayer, while the reduction of landfill fees paid by the private entities is often not reflected in reduced billing [40].

Sustainability

Sustainability is a term that originally referred to the simple concept of continuity of processes, but has expanded to encompass the idea of a larger, if not global, system of operation and life that is sustainable on an ongoing basis. Further definitions include quality of life and ecosystem conservation. The ongoing collision of expanding population and rapid economic development of highly populated countries such as India and China against the older ones of the United States and Europe, finite energy and other natural resource supplies in a competitive globalized economy, and mounting evidence of man-made irreversible changes in various ecosystems have highlighted the need for a change from the immediate, parochial view of industrial manufacturing, marketing, and business.

In a much broader sense, sustainability has been taken in a broader context to mean a variety of things ranging from source reduction and low carbon emissions to complete, low-tech lifestyles. Given that the term originated with researchers studying large-scale agricultural systems perched on the edge of failure, it is easy to see how this interpretation might arise. For an industry concerned with high-speed, minimum-cost manufacturing of disposable goods, implementing sustainability becomes somewhat more indistinct.

Many of the things that can contribute to sustainability in product lines (and their packaging) stem from commonsense implementation of the simple principles outlined earlier, recycling, efficiency improvements, and source reduction. Source reduction includes minimizing the use of materials in both product and packaging manufacture in order to reduce their overall amount before they enter the MSW management system. Examples of source reduction activities are [41]:

- Designing products or packaging to reduce the quantity or the toxicity of the materials used or make them easy to reuse.
- Reusing existing products or packaging, such as re-fillable bottles, re-usable pallets, and re-conditioned barrels and drums.
- Lengthening the lives of products such as tires so fewer need to be produced and therefore fewer need to be disposed of.
- Using packaging that reduces the amount of damage or spoilage to the product.
- Managing non-product organic wastes (e.g., food scraps, yard trimmings) through on-site composting or other alternatives to disposal (e.g., leaving grass clippings on the lawn).

Indeed, as previously mentioned, the "lightweighting" of consumer goods and packaging have contributed to the flattened rate of per capita waste production in the United States that can be seen in Figure 11.11.

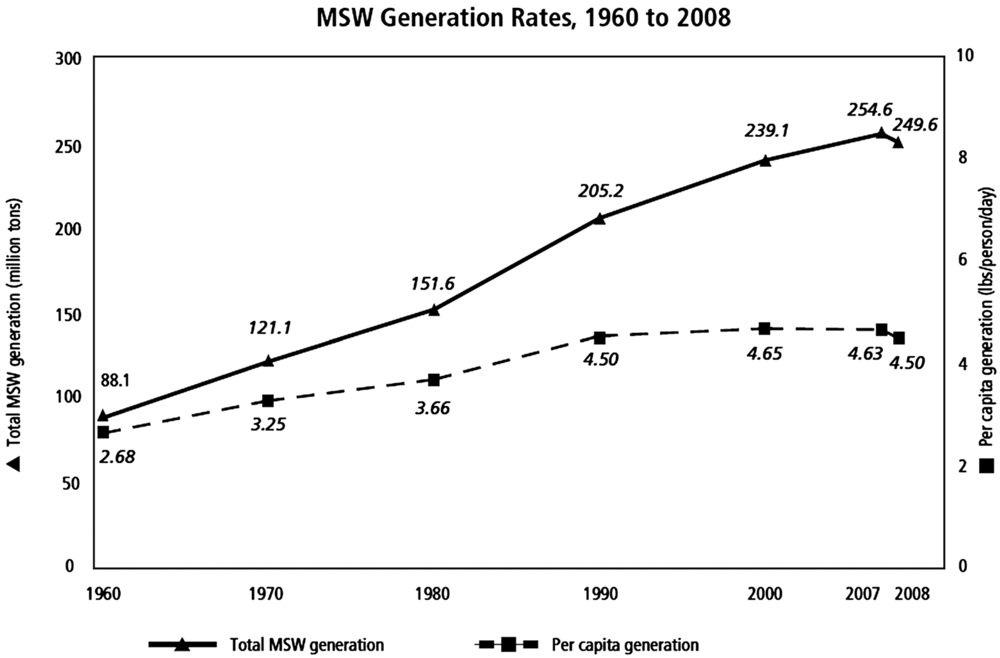

Figure 11.11. US Municipal Solid Waste Per Capita
Source: EPA

From an economic standpoint, sustainability can be managed to not only produce hard-to-measure benefits for society, but can be used to generate a higher rate of profitability by reducing or eliminating waste, re-using materials, and conserving energy. In an economy that concentrates on short-term gains, it is often difficult to focus on longer-term sustainability until a tipping point of resource scarcity, economic shift, or other stress occurs and provides sufficient incentive to overcome the resistance to change from systems that may have been designed for a static model rather than one that recognizes that adaptability and evolution is a key component of economic sustainability. This resistance can range from a time-lag in response because of the complication and investment required to change a large institution, to a complete lack of response based on the belief that the current system is the best available. The food industry, being marketing-driven, often takes a comically over-reactive approach to change in its positioning of products, but is extraordinarily static in its fundamental methods of production. The concept of sustainability has proven to be an agent of change in and of itself, however, helping overcome reluctance to change, and promoting investment in longer-term strategies to cope with increasing changes in the materials and energy systems.

Many of the broader concepts of sustainability can be applied to business operations without significant penalties, and in fact, these may result in long-term profitability and maintenance or improvement of competitiveness [42]. Productivity improvements beyond simple short-term fixes often require capital investment in infrastructure as well as design optimization that often proves more costly. The packaging machinery industry, notoriously stodgy, has begun to implement more efficient integration strategies, though it still lags behind other manufacturing sectors. The food processing industry has always made as much use of raw materials as possible. The industry has capably adapted to rising energy prices in the past by examining resource re-use such as burning waste products to produce energy, but the processing units themselves, already burdened by the demands of cleanliness, flexibility, and immediate production demands and usually without investment capital, are often not integrated and optimized for resource or energy sustainability.

Packaging Sustainability

According to the Sustainable Packaging Coalition, sustainable packaging [43]:

1. Is beneficial, safe, and healthy for individuals and communities throughout its life cycle.
2. Meets market criteria for performance and cost.
3. Is sourced, manufactured, transported, and recycled using renewable energy.
4. Maximizes the use of renewable or recycled source materials.
5. Is manufactured using clean production technologies and best practices.
6. Is made from materials healthy in all probable end-of-life scenarios.
7. Is physically designed to optimize materials and energy.
8. Is effectively recovered and utilized in biological and/or industrial cradle-to-cradle cycles.

Many, if not all, of these goals are focused on economically optimized strategies, which is a constant and unremitting concern in the marginal-expense world of food processing and packaging. Also, few technically complete discussions of how these goals are to be achieved (or who will pay to achieve them) are made. Further, the economics of how the changes will be implemented, and how older production facilities will be treated, had been a matter of vigorous debate. One option, not yet explored in the packaging industry, is the cap-and-trade option of environmental credit trading, similar to carbon, sulfur dioxide, and nitrous oxide emissions trading in the power generation industry, where older facilities are allowed to continue if they buy emissions credits from newer, more efficient plants. This creates an economic incentive for substantial improvement in (or the closing of) older plants, as well as inviting investment in low-emissions designs for newer plants [44]. Additionally it creates an incentive to implement effective partnerships between energy companies and users to conserve sufficient energy to eliminate the need for new power plants altogether. The implementation of this sort of scheme in the packaging industry in a regulatory climate that seeks to minimize government involvement in business affairs may be difficult.

Externalities

The term "externalities" has come to mean the longer-term, more obscure and extended effects of a particular course of action, and is relevant to the concept of sustainability. More formally defined, it means that an externality is a cost or benefit resulting from an economic transaction that is acquired by parties indirectly involved in the transaction. When considering the economic and social outcomes of sustainability in packaging, it is necessary to consider many widely dispersed causes and effects, both economic and otherwise. For instance, the global effects of outsourcing production of plastic resin or container manufacture may be to reduce cost, but it will also inevitably outsource the economic benefits to another location, and will also relocate the resulting pollution, health problems, and secondary economic effects, both good and bad. More strident critics of globalization have pointed out that many countries have essentially exported their problems along with their factories, leaving other communities to deal with the unpleasant secondary effects of the move, often without benefitting from the arrangement.

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