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Environmental Art. Photo courtesy of University of Art and Design Helsinki

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Analysis of the Proposed Solid Waste Interstate Transportation Act of 2005

Trash Transfer Truck. Photo courtesy of Henry Ray Abrams.

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Christine Chase	Nichole Lynch-Cruz
Robin DeJong	Johnny O'Kane
Kristin Heinen	Brian Ross
Nupur Hiremath	Bonnie Stamper
Sallie Lacy	Leo Tidd
Sarah Lopas	Makiko Yamazoe

Faculty Advisor: Dr. Steve Cohen

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Executive Summary

This report analyzes the problem of interstate transportation of solid waste and the solutions proposed by the U.S. House of Representatives Bill No. 274, the Solid Waste Interstate Transportation Act of 2005. The analysis of the Act is broken down into the following components:

Solid Waste Interstate Transportation Act of 2005

This section summarizes the key components of the proposed legislation, which has the overarching purpose of granting state governments the authority to limit the amount of municipal solid waste imported into their state.

The Rationale for the Proposed Legislation

Our report analyzes the rationale of the proposed legislation, particularly examining the environmental impacts associated with solid waste transport and disposal. The management of municipal solid waste is an important function of the government. As the population continues to grow, the amount of municipal solid waste generated continues to grow.

The Environmental Impacts of Solid Waste Transport and Disposal

This section addresses the methods used to transport municipal solid waste, including trucks, barges and trains, as well as the environmental consequences and health risks posed by this transport. The disposal of municipal solid waste also poses environmental and health concerns as well.

Analysis of the Solution Proposed by the Solid Waste Interstate Transportation Act

The Solid Waste Interstate Transportation Act proposes to alleviate some of the problems associated with the transport and disposal of municipal solid waste. However, there are advantages and disadvantages to the proposed policies. The regulation of transport is uncertain, it could increase the mileage of transport as waste is diverted to landfills capable of accepting the waste or it could reduce the mileage of transport by encouraging innovation and/or instate disposal.

The Proposed Solution and their Related Issues and Controversies

Proposed options and solutions that could aid states in complying with the proposed legislation are explored in this section. These include the use of existing technologies, new technologies, and an overall reduction in the amount of waste produced. We also investigate the scientific issues and controversies which surround these proposed methods of waste management.

Measuring the Success of the Solution

The effectiveness of the proposed legislation is only as good as its measurable results. This section considers the means of measuring the legislation's success should it be enacted. Such measurements include the monitoring of air pollution and groundwater pollution, and the distance traveled by municipal solid waste transport.

Solid Waste Interstate Transportation Act of 2005

House Resolution 274: The Solid Waste Interstate Transportation Act of 2005, introduced by Representative Jo Ann Davis of Virginia, amends the Solid Waste Disposal Act.[1] The Act authorizes state governments to limit the amount of out-of-state municipal solid waste that is accepted at individual disposal and incineration facilities in accordance with "host community agreements". A host community agreement is a legally binding contract between a landfill operator and the local government that specifies the terms of operation for the landfill. The Act allows host community agreements to limit the amount of out-of-state municipal solid waste a facility receives. Municipal solid waste is defined by the Act as all materials discarded for disposal by households, hotels and motels; sewage sludge and residuals; combusted ash generated by resource recovery facilities or municipal incinerators; and petroleum contaminated soil. Recycled materials are not considered municipal solid waste for the purposes of regulation under the proposed legislation.

States may limit the annual amount of out-of-state municipal solid waste received to levels documented in 1993 or from the first year of documentation. For new or expanded facilities, the Act authorizes the state to require a permit that allows up to 80% of the municipal solid waste intake of the facility to be from sources within the state. The permit must allow at least 20% of the waste intake to be from out-of-state sources. The percentage limitation on municipal solid waste must be uniform and cannot discriminate against the state-of-origin. If a state has a comprehensive state-wide recycling plan, it may limit the amount of out-of-state municipal solid waste to the amount imported in 1995. The Act also allows the state to require inspectors to be on site during any or all hours of operation at any facility that receives out-of-state municipal solid waste. Under the proposed Act, new host-community agreements may require the owner/operator of the proposed facility to prepare an environmental impact assessment of the site.

The Rationale for the Proposed Legislation

The safe disposal of municipal solid waste is a critical government function that protects public health. For many U.S. states such as New York, in-state municipal solid waste disposal capacity is inadequate for the quantity of waste being produced. Some landfills are nearing full capacity, many have closed, and locations for new facilities are difficult to site, particularly in the Northeast. Currently, several states, including New York, New Jersey and Illinois, have been unsuccessful in siting modern treatment, storage and disposal (TSD) facilities. Combined with the consolidation of the waste management industry, this has necessitated the export of municipal solid waste to other states, including Pennsylvania, Virginia and Michigan, that have numerous, large TSD facilities. Therefore, these states are bearing the long-term environmental and health costs associated with waste they did not produce. Attempts by individual states to limit the import of out-of-state municipal solid waste have been ruled unconstitutional by the U.S. Supreme Court for violating the Commerce Clause of the Constitution such as in the 1978 case *City of Philadelphia v. New Jersey*, and in the 1994 case *C&A Carbone, Inc. et al. v. Clarkstown, New York*.[2,3] Congress has limited power to regulate interstate commerce, which is why states that want to limit municipal solid waste imports are lobbying for this bill to be passed.

According to the Congressional Research Service, 39 million tons of municipal solid waste was imported across state boundaries in 2003, as compared to 14.45 million tons imported in 1993. There was an 11% increase in just two years from 2001 to 2003.[4] Three main factors are behind the increase in interstate transport of municipal solid waste: increased generation, geographic distribution of landfill capacity, and the consolidation of the waste management industry.

Increased Generation

As depicted in Figure 1, per capita was generation has increased from 2.7 pounds per person per day in 1960 to 4.5 pounds in 2003. Total U.S. waste generation has continued to rise since 1990, despite a level rate of per capita generation, due to population growth. Increased generation of waste increases the demand for capacity. Since 55% of generated waste is disposed of in landfills and since some jurisdictions like New York City do not own landfills, increased generation creates an increase in the transportation of municipal solid waste.[5]

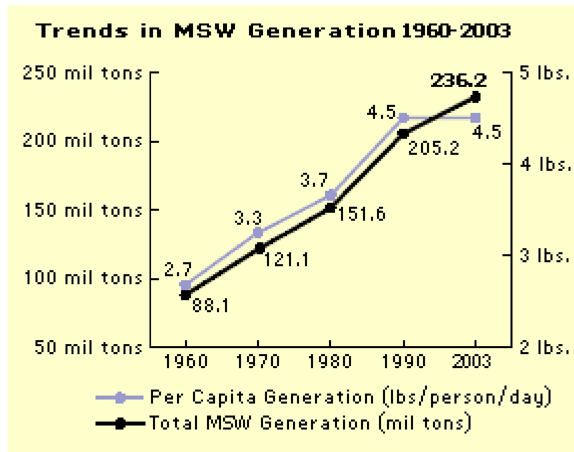


Fig. 1 *Source: U.S. Environmental Protection Agency*

Geographic Distribution of Landfill Capacity

The Congressional Research Service reported that from 1993-2002 the number of U.S. landfills decreased by 54%. However, while small landfills have closed, new massive regional landfills have increased total disposal capacity in the U.S. Although urban centers produce more trash, there is little space around them available for new landfills. The Environmental Protection Agency has strict regulations for landfill siting and management. Ideal landfill sites have specific traits such as topography for leachate collection and a climate that minimizes wind dispersion of contaminants.[6]

Consolidation of Waste Management Industry

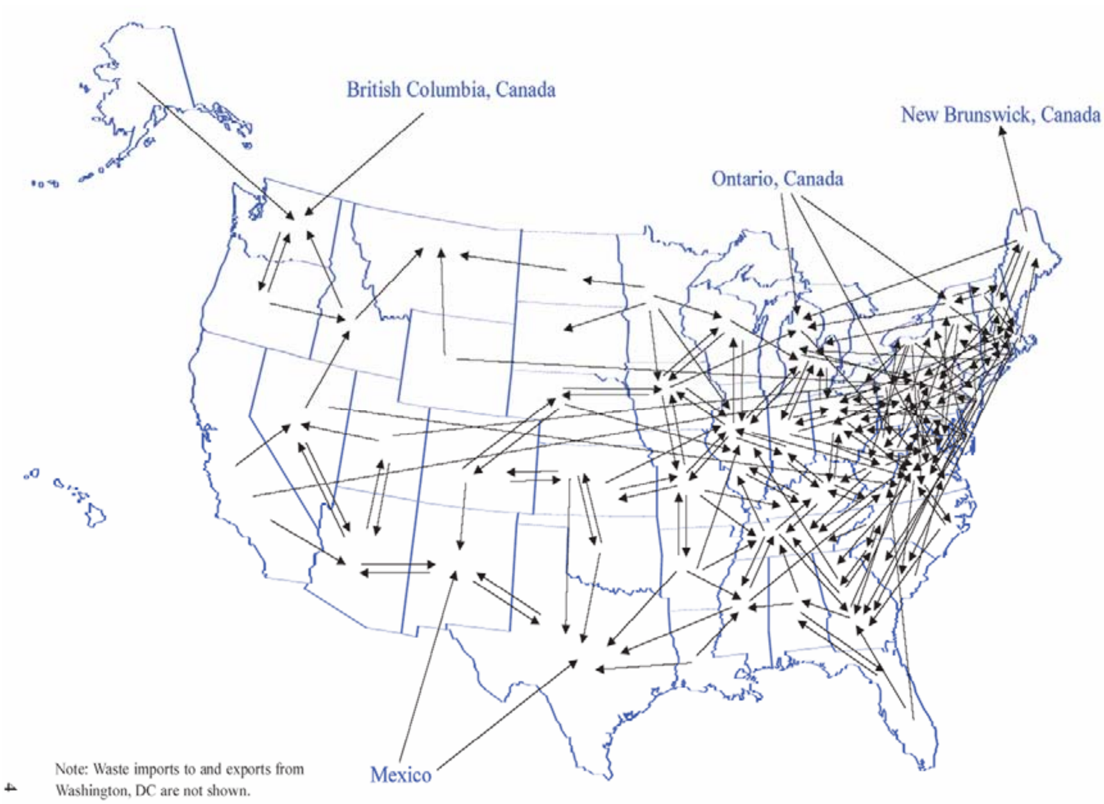
Three companies gross 67% of the revenue earned for U.S. municipal solid waste management – Waste Management, Allied Waste, and Republic Services.[7] As the smaller landfills are closed in favor of large regional landfills, companies prefer to redistribute waste to their own facilities rather than pay competitors with closer landfills to take the waste.

The Environmental Impacts of Solid Waste Transport and Disposal

Transport

In the United States, more than 148,000 vehicles carry nearly 39 million tons of solid waste across state lines each year.[8] These vehicles include diesel trucks, trains and barges. The primary mode of municipal solid waste transport is diesel trucks, because many TSD sites are not accessible by rail and barge transport. Many serious environmental and health risks are associated with diesel trucks and diesel exhaust. Figure 2 illustrates the transport of solid waste across state lines.

Figure 2 Interstate Waste Movements in 2003



Source: National Solid Waste Management Association (http://www.nswma.org/InterstateWaste2005.pdf)

The increase in truck traffic for municipal solid waste transport on the highways leads to congestion and a higher probability of traffic accidents. A study in Houston, Texas, found that 81% of all major freeway incidents, defined as collisions, disabled vehicles and hazardous material spills, in Houston involved large trucks.[9] Almost 60% of traffic congestion in the United States is caused by such incidents.[10]

Diesel engines create an estimated 26% of the national total hazardous particulate air pollution from fuel combustion, and 66% of the national particulate air pollution from on-road sources.[11] According to the Transportation Statistics Bureau Annual Report in 2001, diesel-powered highway vehicles are responsible for 79% of total nitrous oxide emitted by transportation.[12]

Nitrogen oxides emitted by diesel engines can have a number of health effects due to the number of chemical reactions that can occur once they are released into the atmosphere.

Nitric oxide (NO) and nitrogen dioxide (NO_2) are collectively referred to as nitrogen oxides (NO_x) because these compounds rapidly interchange throughout the day. Ultraviolet radiation splits NO_2 into NO and an oxygen molecule. This free oxygen molecule can react with atmospheric oxygen to form ozone, which is a harmful air pollutant in the lower atmosphere. It contributes to smog and can cause deleterious health effects, including lung damage, respiratory irritation, reduced cardiovascular functioning, and possibly some forms of cancer.[13] The presence of ozone in the lower atmosphere is also toxic to plants, reducing photosynthesis and contributing to cell damage that increases vulnerability to disease. NO_2 can also be oxidized to form nitric acid (HNO_3^-), which can form water droplets and fall as acid rain. Atmospheric NO_x can intensify the effect of haze, cause respiratory problems, and be converted and deposited into nitrogen-limited ecosystems causing phytoplankton blooms.

In addition to nitrogen oxide, diesel exhaust is a principle source of the greenhouse gas carbon dioxide (CO_2). Heavy truck emissions have increased by 46% over the last 10 years, and in 2002, they accounted for 83% of CO_2 in U.S. greenhouse gas emissions.[14] Carbon dioxide and other triatomic molecules prevent heat from escaping into space, intensifying the greenhouse effect and thereby contributing to global climate change. Additional air pollutants with health implications from diesel truck emissions include carbon monoxide, various volatile organic compounds, polycyclic aromatic hydrocarbons and particulate matter. Carbon monoxide can chemically asphyxiate humans. Volatile organic compounds (VOCs) can damage liver, kidney and nervous system functioning, and many have been classified by the EPA as potential human carcinogens. Polycyclic aromatic hydrocarbons (PAHs), which are also potentially carcinogenic, can settle out of the atmosphere and accumulate in soils and on surface waters. Particulate matter (PM), such as dust, dirt, soot, smoke, and vaporized pollutants, contributes to smog and haze. Due to its small size, PM can reach deep areas of the lungs, aggravating respiratory illnesses and possibly causing lung cancer.

Train and barge transport are less frequently used in the transportation of MSW, yet, their impact cannot be disregarded because their large carrying capacity increases the potential harm from an accident. The spill of waste or fuel directly into water from a barge spill is particularly difficult to clean up. These negative environmental and health effects are all related to the transport of waste. However, once the municipal solid waste reaches its final destination, there are additional environmental and health hazards inherent in the disposal methods.

Disposal

<u>Landfills</u>

Landfills are shallow depressions in the ground that are typically lined with a two-foot layer of clay and high-density plastic liner that is designed to prevent contamination of underlying soil and groundwater. Landfills are the disposal method of 56% of all municipal solid waste.

One byproduct of landfills is leachate, formed when rainwater and liquid waste percolates through solid waste, absorbing contaminants including heavy metals, salts, xenobiotic organic compounds, and dissolved organic matter. Heavy metals derived from industrial wastes and electronics include lead, cadmium, mercury, arsenic and chromium. Increased levels of salts can disrupt microbial populations and make groundwater undrinkable. Xenobiotic organic compounds include polychlorinated biphenyls (PCBs), pesticides, solvents, gasoline, and oil, and can be particularly difficult to remediate if they are highly concentrated. Dissolved organic matter, such as breakdown products of food and paper waste, can change redox conditions in groundwater, and if discharged to surface waters, can promote algal blooms.[15] Groundwater contamination can persist because of the long residence time of the hydrologic cycle. Leachate contamination of groundwater is of particular importance because it can make drinking water unsafe for consumption.

In the U.S., the most serious impact of landfills is contamination of groundwater. Groundwater supplies the drinking water for 51% of the total population of the U.S., and 99% of the rural population.[16] Early landfills were nothing more than open dumps, which quickly led to a number of sanitation and health issues. Newer landfills include a leachate collection system, and all are periodically covered with several inches of soil to create "cells" of waste.[17] Some landfills, especially older landfills, do not have leachate collection and treatment systems. The EPA acknowledges that "the best liner and leachate collection system will ultimately fail due to natural deterioration," and that improving technologies simply prolong the onset of this failure.[18]

Another byproduct of a landfill is air pollution. Landfill emissions contain about 30 of the 188 toxic air pollutants listed for regulation under the Clean Air Act.[19] In the U.S., landfills are the single largest human-related source of methane emissions, accounting for 34% of the total emissions.[20] Aerobic decomposition of biodegradable organic wastes results in oxygen and organic matter to be converted to methane (CH_4) and CO_2. Methane and carbon dioxide equally account for 90% of total gas generated during anaerobic decomposition. Methane is a potent greenhouse gas; the effect of one methane molecule on global warming is 20 times greater than one molecule of carbon dioxide.[21] Methane gas is especially dangerous because at certain concentrations it is highly explosive. This is particularly important when gas is not vented and instead migrates through the soil. By diffusing through the soil, methane can enter underground structures such as basements and utility spaces and create explosion hazards.[7, 22] Additional contaminants that can be present in landfill gases include polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs) which can migrate upwards through the soil, killing vegetation as they replace oxygen or potentially contaminating groundwater aquifers.

Incinerators

Fourteen percent of municipal solid waste generated in the U.S. is incinerated.[23] Incinerators involve the combustion of solid, liquid or gaseous wastes and can reduce waste weight by 70%. The resultant heat of combustion can be used to generate electricity. Municipal solid waste incinerators generally involve the following processes: waste storage and handling; processing to prepare wastes; combustion; air pollution control; and residue (ash) handling.[24] The combustion process involves a rapid, exothermic reaction between fuel and oxygen resulting in carbon dioxide, water and ash. The ash is either disposed of at a landfill or reused for construction purposes. Inefficient combustion results in the presence of contaminants that were either present prior to incineration or were formed during incomplete combustion and in the gas cooling stage.

These pollutants can either be contained in the bottom ash or released in gaseous form from the incinerator smoke stack.

There are four categories of incinerator pollutants: gases, metals, organic substances, and particulate matter.[25] Gases include highly acidic gases such as NO_x that can form cloud droplets and fall to the ground as acid rain. Metals that are not destroyed in the combustion process include mercury, cadmium, chromium, lead, manganese, cobalt, vanadium, copper, nickel, thallium, and arsenic. These metals can bind to particulate matter in the fly ash which in turn can be inhaled by humans, or can settle on soils and water, adversely affecting the various systems of the body and possibly leading to cancer. Additionally, organic matter formed by incomplete combustion includes dioxins and furans, which have been linked to cancer and may cause reproductive or developmental problems. However, new incinerator technologies have improved combustion and decreased the amount of air pollutants emitted.

Analysis of the Solution Proposed by the Solid Waste Interstate Transportation Act

All forms of municipal solid waste management pollute the environment. Impacts range from local soil contamination to regional groundwater pollution, and can also affect national air quality and influence global climate change. Every policy solution to this problem comes with advantages and disadvantages. The key to effective policy is to identify cost effective methods that generate the most protection for the least cost.

<u>Advantages</u>

An advantage of limiting MSW imports is that it enhances the ability of states to limit the contaminants that currently enter the state's ecosystem through imported waste. One of the major complaints from importing states is that they act as the dumping ground for the waste and contaminants produced by exporting states.[26] Some of the toxics and heavy metals in decomposing MSW degrade very slowly or not at all.[27] If states limit MSW imports, then they will reduce the volume of contaminants in their environment.

Another advantage to this legislation is that interstate transport limitations and subsequent higher disposal costs can promote innovation to the waste management industry and increase efforts toward waste reduction. The Solid Waste Interstate Transportation Act creates incentives for local waste disposal. Local disposal is important for lowering the environmental impact of transportation and allowing states to protect themselves from excessive imports. Alternative MSW management technologies can be comparatively cost-effective and develop into viable options. Governments could study waste conservation and recycling programs, as in 1999 when Maryland Governor Parris N. Glendening ordered a waste management task force to make recommendations for improving on the state's MSW exports while considering possible passage of legislation similar to the Act.[28] Reduction in the produced volume of MSW solves the root problem behind arguments over MSW interstate transport.

A final advantage would be the long term benefits received by states able to limit the amount of imported MSW. The true cost of contamination remediation is not reflected in MSW disposal costs. A report by the Minnesota Pollution Control Agency found that landfill closure, post-closure, and corrective actions can last 30 years, and host states must bear the costs.[29] Import limits would cut these costs, put more responsibility on the waste-producing states, and decrease demand for landfills in some states. More land would be available for alternative development or conservation. For example, Virginia imports the second highest volume of MSW in the country.[30] Currently, Virginia protects 12 percent of its estimated total land area for conservation – 3 million acres conserved out of 25.27 million total acres.[31] If Virginia's waste imports decrease, there will be less pressure to develop these lands into MSW disposal sites.

Disadvantages

The limitation of amount of MSW to cross state lines could actually lead to longer transportation routes in some cases. For example, in Cook County, IL, where Chicago is located, landfills are closer out-of-state in Southern Wisconsin and Northwest Indiana than in downstate Illinois landfills. Even though Illinois doubled landfill capacity from 1994 to 2003, the state also exported twice the volume of MSW. The increased landfill capacity accommodated St. Louis and its suburbs – not Chicago.[32]

Another disadvantage would be the potential for sitting a landfill in an inappropriate location. In general, landfills are located with regard to natural conditions like topography and climate to minimize dispersion of contaminants to nearby residents through the ground and air.[33] MSW import limits may lead to poorly sited landfills in less than ideal natural conditions that may increase the risk of contamination. Unfortunately, current alternatives to landfills are either not cost-effective or too dangerous for the environment. For example, waste incinerators were prevalent in many U.S. cities through the mid-1960s, but studies found that emissions contained several harmful contaminants. As of 2001, proper emission remediation technology was too expensive and high operating costs increased demand for cheaper landfills.[34]

A further disadvantage would be the immediate costs of changes in the waste management industry. Some landfills have closed in urban centers because of lawsuits over their negative health effects, as was the case with the Fresh Kills facility on Staten Island in New York.[35] If previously closed facilities are reopened or existing landfills are expanded to handle additional MSW, then there will be added strain on their host communities. If MSW import limitations are imposed, then the waste management industry will be forced to reverse its policies and practices by suspending consolidation of the industry. Many waste managers currently rely on imported waste for revenue.[36] If there is less waste imported to landfills, there will be fewer tipping fees paid and less income for landfill operators. With less revenue to cover costs, landfill operators will earn less profit. Under short supply and unchanging demand, the price of a product increases – in this case the price of waste disposal. Therefore, residents in both importing and exporting states will have to cover the costs of this policy.

Uncertainties of HR 274

The impact of this bill is difficult to project. One potential benefit of the Act is that it encourages exporters to manage their waste locally instead of passing it on to other states. On the other hand a state might simply bypass the state reluctant to accept waste and ship it further to a state more interested in the waste disposal industry. Whatever the states choose to do after they are granted that power and whatever technological or political developments result from their choice, it is difficult to forecast the behavior of state and local waste management officials. The reaction to this new regulation may be different for each state.

While state behavior is uncertain, we are certain that a smaller volume of MSW results in fewer air and water contaminants. Importing states will focus on management of their MSW and remediation of their disposal sites. Exporting states will pay higher transport costs, limit waste production, and/or improve their MSW management plans.

The Proposed Solutions and their Related Issues and Controversies

The Act encourages exporting states to find more effective and benign ways of disposing their MSW within their own borders. The states may move toward a model of self-sufficiency and environmentally sound treatment since they may be bearing increased environmental and health effects due to MSW treatment. This can be achieved through the application of existing technology, the application of new technology, and a reduction in the volume of MSW.

However, a number of scientific issues accompany the implementation and extensive use of any of the three categories of proposed solutions. While these new technological solutions can partially reduce MSW volume, or reduce the environmental impacts of existing landfills, they are currently not being used on a large-scale in the United States. With the increasingly urgent problem of municipal solid waste to be contained locally, there must be further research to overcome the scientific hurdles. The ultimate "solution" may be a utilization of several proposed techniques.

Existing Technology

Currently, a variety of methods are being used to manage solid waste in the United States. For instance, New York state uses MSW landfills, Refuse Derived Fuel (RDF) incinerators, solid waste incinerators, composting, pyrolysis, waste tire storage, leachate storage facilities, landfill gas recovery facilities, solid waste incinerator ash residue monofills, construction and demolition waste landfills and used oil transfer and storage facilities.[37] However, although the list is comprehensive, the most common disposal methods are landfills and incinerators. There are several alternatives to the use of landfills and incinerators that significantly have fewer associated environmental and health risks, such as anaerobic digestion and thermal gasification.

<u>Anaerobic Digestion or Fermentation</u>
Anaerobic digestion is the process by which microorganisms can be used to digest solid waste in an oxygen free environment.[38] This involves the conversion of larger organic wastes into smaller, more manageable ones.[39] It also releases a mixture of carbon dioxide and methane called biogas that can then be used as fuel due to its combustibility.[40]

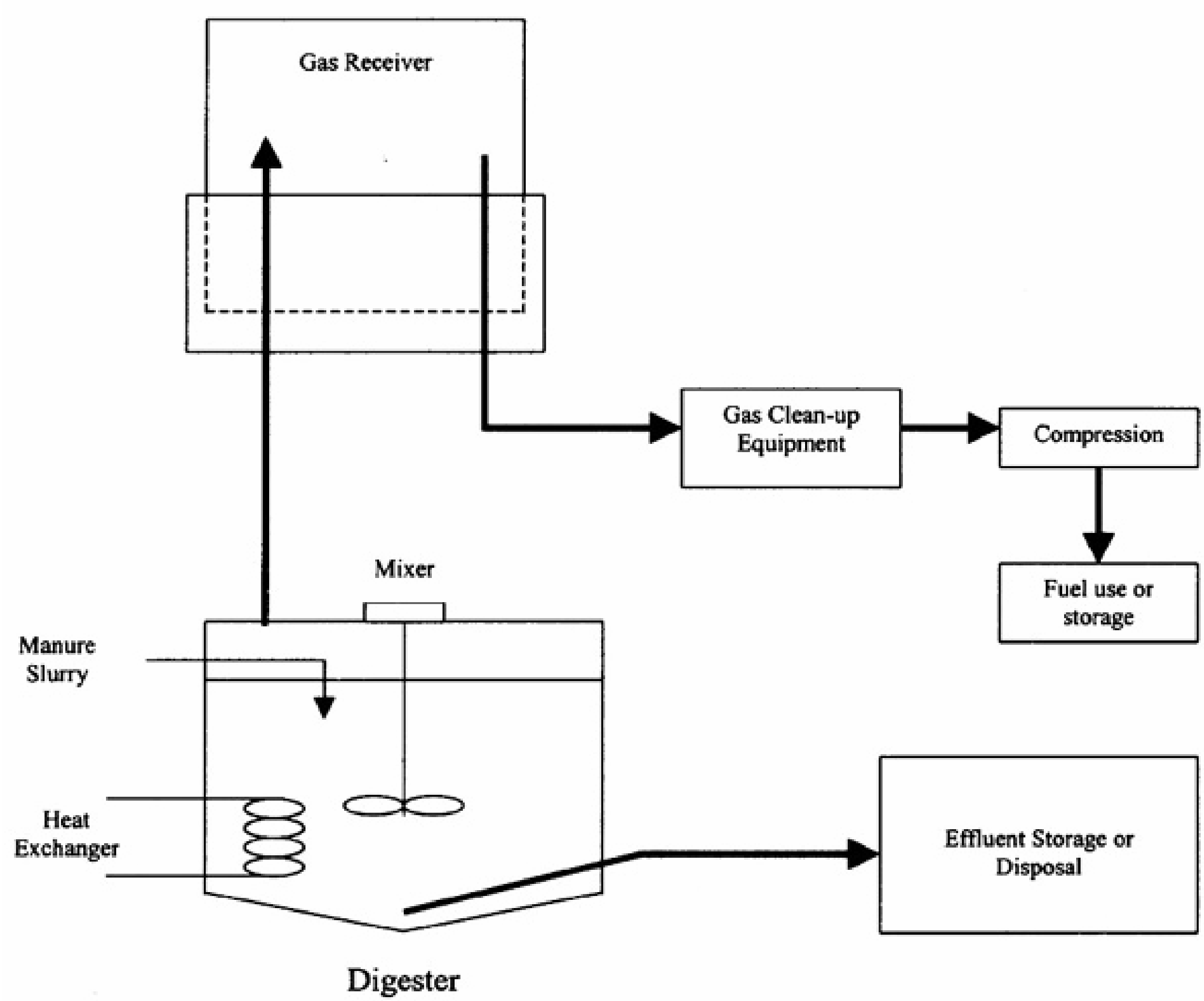


Figure 3 Anaerobic Digestion Tank. MSW is placed in the digester where it is heated through a heat exchanger and simultaneously mixed with a powerful mixer. The resultant waste is taken to an effluent storage tank or a disposal tank. The gas released is collected in a gas receiver, cleaned, compressed under pressure, and subsequently used as fuel or stored for later use.[41]
Image Source: National Agriculture Information Service.

Thermal Gasification & Pyrolysis

Thermal gasification and pyrolysis are often used in conjunction with each other. Pyrolysis involves the combustion of MSW in the presence of a limited amount of oxygen.[42] The purpose of this is to first anaerobically decompose the bulk of the organic material into smaller components, after which the remaining material is oxidized. The resultant biogas, comprised predominantly of methane and carbon dioxide, is recycled into the system and used to fuel the subsequent stages of the process.[43] Thus, gasification is used to maintain the temperature of the gasifier so that no additional heat needs to be provided. In most cases, the digested material is collected as char and further used as fuel.[44] The set up for thermal gasification is similar to that for anaerobic digestion, except that digestion in gasification occurs in the absence of microorganisms.

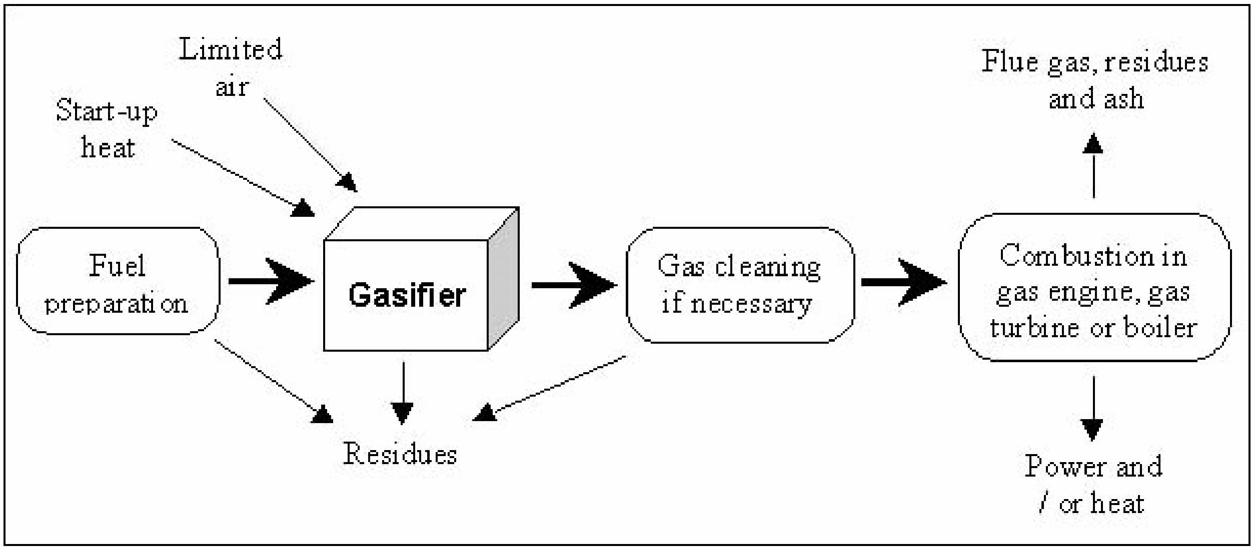


Figure 4 Thermal gasification process. MSW is placed in a closed gasifier, a limited oxygen atmosphere, where it is provided with start-up heat. The subsequent residues are collected while the biogas released is cleaned and used for combustion.[45]
Image Source: Cardiff University Waste Research Station.

Issues and Controversies

The anaerobic digestion process is similar to the natural biodegradation of MSW in landfills. The danger from this process may be the release of biogas, consisting primarily of methane, into the atmosphere either from inefficient processing or from overproduction. In addition to being a potent greenhouse gas, methane is difficult to detect and therefore could pose an occupational hazard. Methane is potentially explosive and can react with hydrogen sulfide to form a deadly poison as it displaces oxygen.[46] Besides biogas, anaerobic digestion produces sludge. The consequences of using this sludge as a fertilizer have not yet been determined, and a lack of a market for sludge inhibits the financial investment into developing anaerobic digestion. Another limiting factor is that anaerobic digestion can only process organic wastes, such as yard clipping and food wastes, which means that it can only reduce a portion of the volume of solid waste. While utilization of a pre-processor can separate the recyclables, thereby effectively reducing the solid waste, this requires additional area for siting the pre-processor.

The biggest advantage of processing MSW by means of pyrolysis and thermal gasification is that pollutants such as sulfur are retained, rather than being transformed into the gas phase and allowed to enter the atmosphere, as is the case with incinerators.[47] However, this only displaces the problem to the disposal of the resultant ash. In addition, EPA lists emissions for a “starved-air combustor” the most closely related process and demonstrates that other contaminants are present in the flue gas similar to incinerators. Other considerations include the cleaning of the biogas so that it can be used as energy, and the shredding of the MSW. The re-circulated biogas in thermal gasification must be cleansed of tars and particulate matter in order to maintain efficiency and protect the equipment. However, the “scrubbing” of the biogas at high temperatures has yet to be established on a large scale and is currently being researched.[48] The MSW must be shredded prior to being added to the gasifier, which requires labor and is cost-intensive.[49]

With both thermal gasification and anaerobic digestion, the biogas power plant must be located nearby since it is impractical to transport biogas over large distances.[50] This also poses a problem for the land requirement of siting the anaerobic digester or the gasifier near a biogas power plant, which is recommended to be located near an urban center. However, these methods work well for the organic component of MSW. In a report by the New York State Department of Environmental Conservation, a large proportion of the MSW of the state consists of food residual wastes from households, hospitals, nursing homes, prisons, and amusement parks.[51] Over 233,000 tons of organic waste was recycled by New York State in 1998.[52] Food waste can be up to 10.4% of the total waste generated in the United States.[53] Thus, given that organic wastes contribute significantly to the bulk of MSW in most parts of the United States, it would be worthwhile to employ thermal gasification and pyrolysis as well as anaerobic digestion to process the MSW, rather than depending heavily on its export to other states.

New Technology

New techniques are currently being applied to landfills, incinerators, and waste-to-energy (WTE) plants to make them more efficient and less polluting. Presently, WTE plants throughout the world combust approximately 130 million tons of solid waste every year.[54] The combustion process in these plants is much cleaner than that in traditional incinerators, showing significant reduction in emissions of greenhouse gases and volatile and chlorinated organic compounds. Moreover, MSW represents a renewable energy source when gases released during its processing are recovered through WTE. Additionally, the processes of anaerobic digestion and thermal gasification are becoming increasingly efficient through the introduction of catalysts such as effective microorganisms and methanogenic reactors.[55]

<u>Biostabilization in Bioreactor Landfills</u>
Biostabilization of MSW involves the treatment of MSW until it has achieved its lowest biological oxygen demand and has produced the maximum possible carbon dioxide and methane. At this point, degradable organic matter and further microbial activity is at a minimum.[56] This process allows biostabilization of MSW to occur in a period of 5-10 years, rather than the decades it takes for the same decomposition in traditional landfills.[57] Certain bioreactor landfills lead to an increase in the amount of methane produced since it can be used for energy production, while some bioreactor landfills lead to a decrease in the amount of methane produced thereby alleviating the environmental impact of a traditional landfill. A facultative bioreactor allows for the release of nitrogen, which has a lower environmental impact than methane. When the leachate is recycled into the landfill, the denitrifying bacteria in the MSW break down the nitrates and convert them to nitrogen gas.[58] Thus, bioreactor landfills are an alternative that prove to be more energy-efficient and have less pollution potential than traditional landfills.

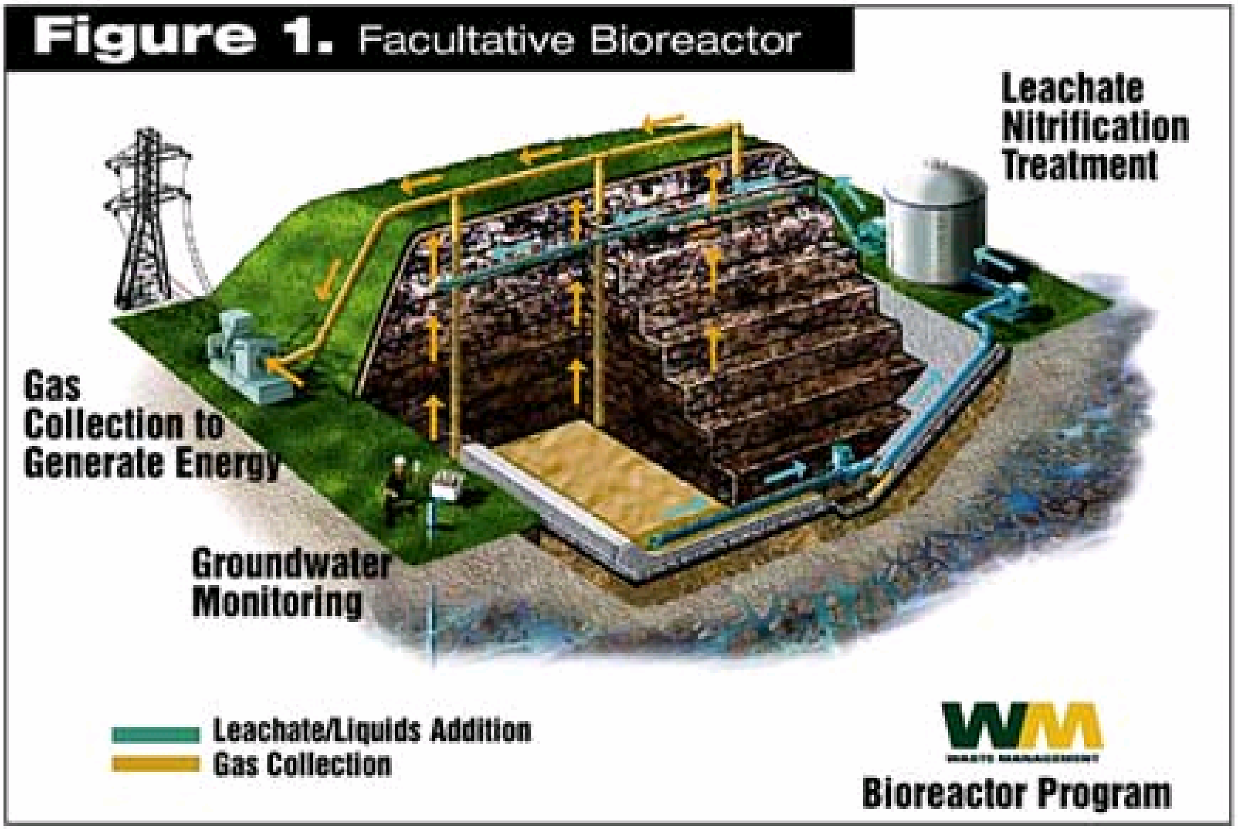


Figure 5 Schematic representation of a bioreactor landfill. Leachate is tapped from the bottom of the landfill (blue pipe) and taken to a leachate nitrification plant where the ammonium compounds in the leachate are converted to nitrates. Treated leachate is then recirculated through the landfill (blue pipes). Methane gas released (yellow pipes) can still be tapped for energy.
Image Source: Markwiese et al., Journal of Municipal Solid Waste.[59]

Oxygen Enriched Air and Flue Gas Recirculation

Currently, most WTE facilities operate on a mass-burn system, as this represents the cheapest and simplest way to reduce volume of MSW and recover energy produced during this process.[60] In an effort to further improve the existing technology, new systems are continually being introduced into the market.

One of these is the Martin GmbH SYNCOM-Plus process, a highly sophisticated WTE process that re-circulates flue gas in order to increase turbulence and transport within the WTE chamber, resulting in more complete combustion of MSW.[61] Since the flue gases are hot from the combustion process, they help to maintain the temperature of the waste bed at adequately high temperatures, to the order of 1150^{o}C, thereby reducing the energy demand in the later stages.[62] Recirculation also helps reduce the volume of flue gases release by 35%, thereby leading to a reduction in the pollutants associated with flue gases, such as fly ash.[63] This bottom ash, following treatment, can be beneficially used in making road surfacing materials.[64]

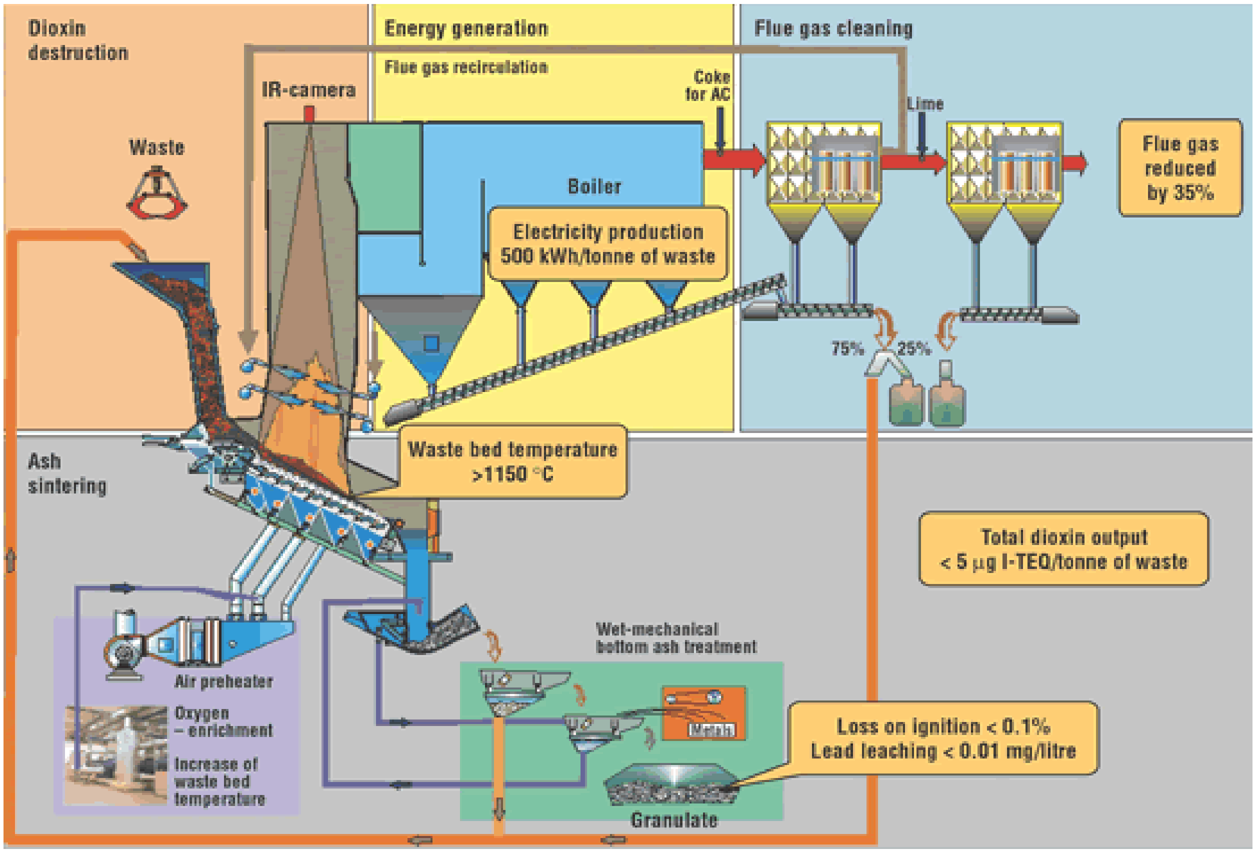


Figure 6 Martin GmbH SYNCOM-Plus process. MSW enters the waste bed, where temperature is monitored by an infrared camera. Flue gas is re-circulated from the flue gas cleaning chamber and, along with oxygen, is injected through the grate, increasing the temperature of the waste bed. This results in a higher quality of bottom ash, which can then be used beneficially.[65]

Image source: Themelis, N. J, Waste Management World, 2003.

Combustion (Fuel) Cells

Although fuel cells have historically been intended for use in space vehicles, they are now being considered as an emerging technology for electricity production derived from gases generated during the stabilization of MSW.[66] They are an attractive alternative for electricity because of their efficiency and minimal emission of polluting gases. The design of a fuel cell consists of two porous electrodes that are separated by an electrolyte. As reactions occur between the electrodes, hydrogen and oxygen are consumed, producing water and electricity. The electrolyte conducts the ions produced and consumed during these reactions, thereby closing the electrical circuit within the cell. Heat produced during these processes must be removed to maintain the cell's temperature. As a single cell only generates approximately 0.7 Volts of power, multiple cells are assembled into "stacks", and multiple stacks form "modules" that generate a higher degree of power.[67] The water produced in the process is converted to steam which then drives turbines that further generate electricity.[68]

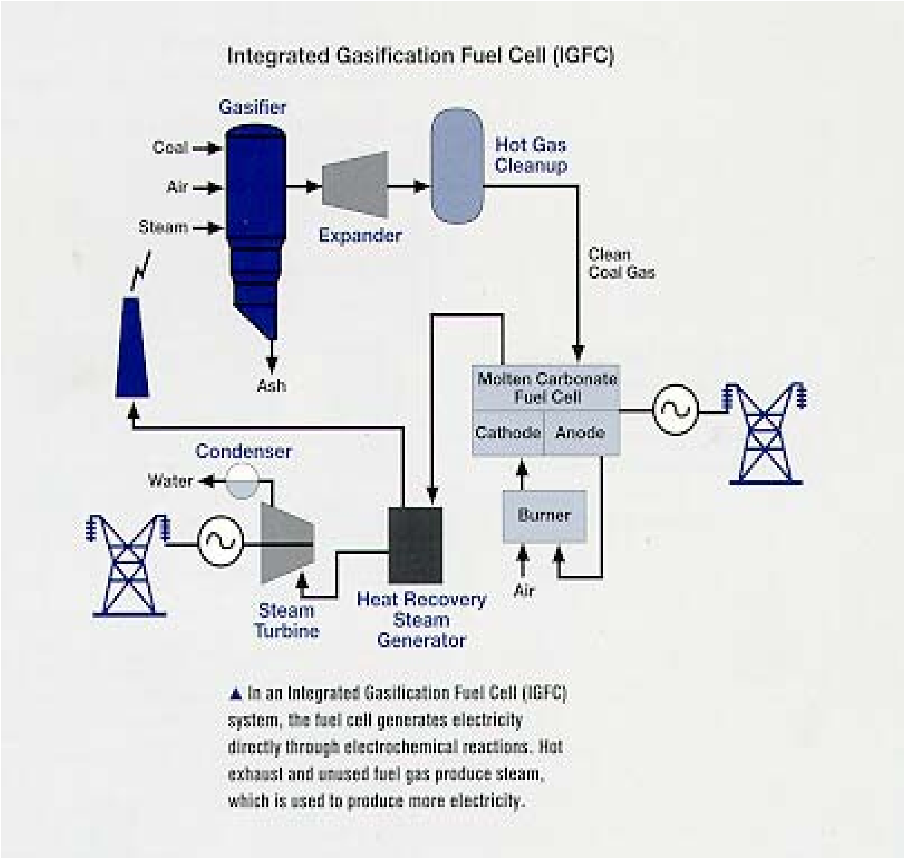


Figure 7 Schematic representation of one of many possible designs of machinery that can use biogas from waste treatment (in this case, gasification) in fuel cell technology. Hydrogen is extracted from cleaned biogas and channeled into a molten carbonate fuel cell where it reacts with oxygen via electrolysis to generate electricity. Water produced is converted to steam which then drives a steam turbine, further generating electricity.
Image Source: Energy Conversion Systems.[69]

Issues and Controversies

A major issue with the biostabilization (bioreactor) is maintaining the moisture required for efficient processing. Leachate alone is usually not sufficient, so additional sources are required, including storm water, wastewater and wastewater treated sludge.[70] Since MSW is heterogeneous, this presents a problem with "dry zones", or regions where the moisture is not adequately distributed, increasing the time necessary to reach biostabilization. This can be remedied by efficient subsurface techniques like vertical and horizontal trenches, but due to the novelty of this technique, there is no existing design guideline.[71] In addition, the EPA lists the following "special considerations" that will need to be researched: increased gas emissions, odors, instability of waste mass with increased moisture and density, possible failing of liner systems, surface seeps and landfill fires.[72]

The technology of oxygen air enrichment and flue gas recirculation is still in its developing phase, and more research needs to be done to determine efficiency and to ensure safety. The U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy proposed ways to reduce energy inefficiency and possible NO_x emissions in a report in 2004, which would take at least three years to develop.[73]

Since fuel cells only utilize the emitted landfill gas, they are not a direct reduction of MSW and must be used in conjunction with traditional landfills. The advantages of this technology are that energy conversion through cells is relatively high (on the order of 40%-60%) and it is fueled by hydrogen, which can be extracted from waste compounds, such as methane, natural gas, and biomasses.[74] However, the landfill gas must be pre-treated for sulfur and halide in order to avoid the reduction of the life and efficiency of the fuel processor. Additional potential areas of problems include issues with conductivity, the catalyst process and other design considerations. However, the main reason that fuel cells are not used is because it requires six times more electricity as a conventional gas plant, making this solution expensive to develop. Moreover, it is not projected to be used widely for another 10 or 15 years.[75]

Volume Reduction

<u>Source Reduction</u>

Source reduction refers to methods that "reduce the amount or toxicity of trash created".[76] Source reduction is the most effective way to reduce the production of MSW. Typical methods of source reduction include the use of less bulky packaging, reusing goods, and buying recycled or durable goods. The best way to promote source reduction is through public education campaigns that encourage people to be conscious of the number and type of products they purchase.

Source reduction is based on the principle that preventing the creation of waste is more economical than having to treat the waste when it already exists. Source reduction also prevents some of the life cycle environmental impacts. By reusing more and buying less, the total impact of all the resources used is reduced, not simply the impact on the waste system. For instance, the reduction in the mass of 2 liter soft drink bottles from 68 to 51 grams prevented 250 million pounds of waste per year.[77] Thus, the bottle mass reduction has benefits in lowering the need for raw materials at the creation side of the lifecycle.

Another area of source reduction success is reuse of existing materials. For example, thrift stores like the Salvation Army sell used items. The Reuse Development Organization estimates there are more than 6,000 reuse centers in the country, including specialized centers for items like building materials.[78]

A growing area of interest in source reduction is a disposal fee for consumers based on the amount of waste they produce. This economic incentive is the most direct way to force consumers to produce less waste. Fee systems can have some management challenges in measuring waste production by specific sources, particularly in high density urban environments. There is also the problem of the impetus for illegal dumping when charges for disposal are high.

<u>Recycling</u>

Recycling is the process of breakdown of existing products into their component materials to regenerate new products. It usually requires extensive reprocessing and uses more energy than preventing the production of waste in the first place. Nevertheless, it is preferable to landfill or incinerator disposal.

Significant progress has been made in recycling in the U.S.; the current recycling rates are about 28% of the total waste, almost twice the rate from 15 years ago. In 1999 alone, approximately 64 million tons of material was kept out of landfills and incinerators by recycling and composting activities. According to the EPA, the U.S. recycles about 42% of paper, 40% of plastic soft drink bottles, 55% of aluminum cans, 57% of steel packaging, and 52% of all major appliances.[79] States with a bottle deposit program are likely to have a high total recycling rate. The states with bottle deposit programs are California, Connecticut, Delaware, Iowa, Maine, Massachusetts, Michigan, New York, Oregon, and Vermont.

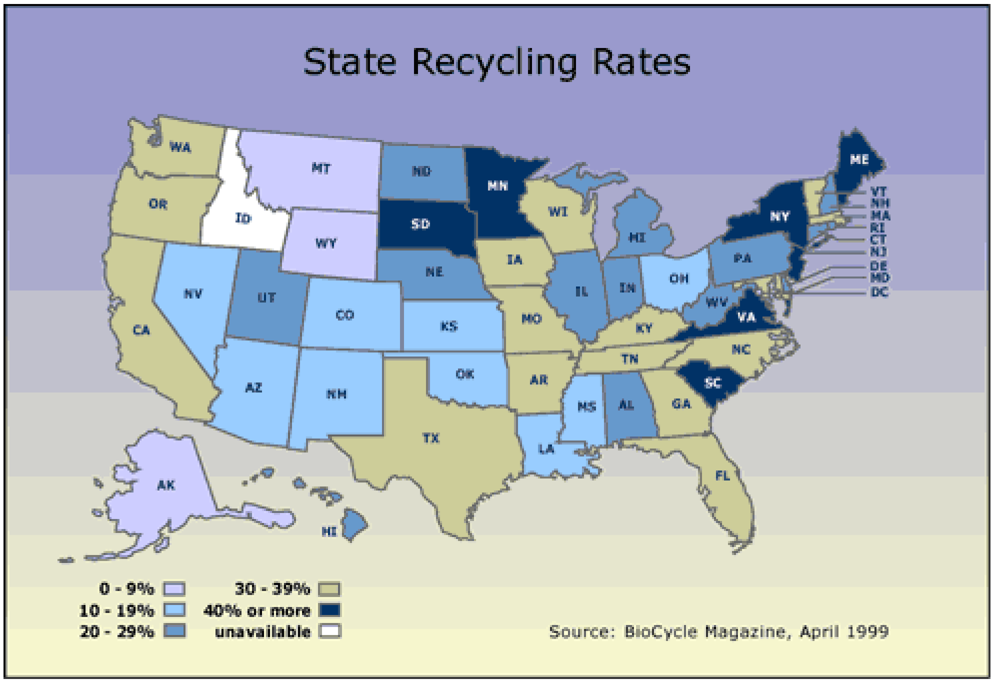


Figure 8 Map showing distribution of recycling rates in the United States
Image Source: EPA.[80]

Recycling has become a growing business area as people develop new ideas for what can be made from recycled products. King County, Washington has an innovative recycled materials market development program, called Linkup. Linkup assists businesses by providing services such as material and product testing, market research, material sourcing, and media campaigns; developing marketing materials such as brochures, case studies, and specification sheets; and facilitating business and strategic planning for recycling.[81]

The most common forms of recycling are of plastic, glass, aluminum and paper from municipal areas. These materials are collected from households by recycling companies. In certain states, residents are allowed to collect recyclables of different materials in the same container.[82] In such cases, these are sorted once they are taken to a Materials Recovery Facility (MRF). Other states encourage residents to sort recyclables based on material content into separate bins by a process known as source separation.

Issues and Controversies

Public awareness requires diligent communication and effective tools to ensure its success by effectively modifying behaviors. In order to maintain long-term program success, the public needs to understand “what behaviors are desired and why.”[83] Therefore, public awareness needs to be consistent in its message and ongoing with its efforts. The most effective public awareness program will have approximately 50% participation of the population, with a later gain of 30% as the program progresses.[84]

Recycling can result in a substantial reduction of waste volume, but there are potential problems with the processing. One of the problems is determining whether collection should occur at a central location, a Materials Treatment Facility, or at individual residences. While a central location requires less transport, it decreases the amount of materials recycled. Recycling also requires development of an infrastructure, including extra administrators, a continuous public relations campaign, and possible enforcement agents to inspect garbage and issue tickets.[85] There is also a need for an effective education plan because the efficiency of the recycling process is dependent upon whether or not the materials are recycled properly. Since many individuals may have difficulties sorting a variety of products, separation could be conducted after general collection, but this requires funds that may not be readily available. Another problem is the market for these recyclables, because if the product is not needed, it will return to the landfill or incinerator. This may reduce the amount of recycling, since it underscores public confidence in the recycling process.

Measuring the Success of the Solution

Municipal solid waste is disposed of by three main processes: landfill, incineration, and interstate transport. Each process produces its own set of pollutants. The success of the Act can be measured by reduction in transportation of MSW and reduction of environmental and health impacts caused by the interstate transport and disposal of MSW. These two categories can be measured with quantitative environmental indicators such as the distance MSW is transported out-of-state and the amount of emissions produced by MSW transport and disposal. For the purposes of this report, an environmental indicator is defined as “a parameter or a value derived from parameters, which points to, provides information about, or describes the state of phenomenon/environmental/area, with a significance extending beyond that directly associated with a parameter value.”[86] Examples of useful environmental indicators for landfill, incineration, and interstate transport are listed in Table 1.

Table 1: List of Scientific Indicators

Landfill	Incineration	Transport
Landfill gases • Methane • Carbon Dioxide **Groundwater contaminant** • Lead • Cadmium • Mercury • Arsenic • Chromium • Salts • Xenobiotic organic	**Air pollutant** • Hydrogen chloride • Hydrogen fluoride • Sulfuric dioxide vapors • Nitrogen Oxides • Dioxins • Furans • Particulate Matter • Lead • Cadmium • Mercury • Arsenic	**Air pollutant** • Nitrogen Oxides • Carbon Dioxide • VOCs • Ozone • Particulate Matter **Spills** • Nitrates • Ammonia • Iron • Copper

Landfill	Incineration	Transport
compound • PCBs • VOCs • Ozone	• Chromium • Cobalt • Vanadium • Copper • Nickel • Thallium	• Chromium • Lead • Cadmium

Many of the above indicators have not been measured sufficiently to be used to evaluate the success of the bill. The Environmental Protection Agency (EPA) measures some of the indicators listed in Table 1 and compiles them in three major data sets: Air Quality System (AQS), National Air Pollutant Emission Trends (NAPET), and Inventory of U.S. Greenhouse Gas Emissions and Sinks (U.S. GHG). The data reported by these data sets are summarized in the Table 2.

Table 2: Scientific Indicators Reported by Existing Data Sets

Data Set	Data Source	Landfill	Incineration	Transport
Air Quality System (AQS)	AQS provides raw ambient air quality data. It is compiled daily from state and local organizations that monitor air quality in their particular region and submit their data to the EPA.	Does not compile data by emission source.	Does not compile data by emission source.	Does not compile data by emission source.
The National Air Pollutant Emission Trends (NAPET)	NAPET is compiled annually and provides emission data by category including landfills, incineration, and transportation. The data is based on the baseline data and EPA's projections.	• Carbon Monoxide (CO) • Ammonia (NH_3) • Nitrogen Oxide (NO) • PM-10 • PM-2.5 • Volatile Organic Compound (VOC) • Sulfur Dioxide (SO_2)	• CO • NH_3 • NO • PM-10 • PM-2.5 • VOC • SO_2	• CO • NH_3 • NO • PM-10 • PM-2.5 • VOC • SO_2
The Inventory of U.S. greenhouse	The greenhouse gas inventory data is compiled annually based on IPCC	• Methane	• Nitrous Oxide • Nitrogen Oxide • Non methane volatile organic	• Carbon Dioxide • Methane • Nitrous

gas emissions and sinks data	guideline. Air Quality System data provides baseline data for the inventory data.		compounds (NMVOCs) • Carbon • Monoxide • Sulfur Dioxide • Carbon Dioxide	Oxide • Hydro-fluoro-carbons

These data sets are derived through the direct and indirect measure of emissions produced from landfills and incinerators. The NAPET data set is more comprehensive and more useful for measuring the success of the bill than the AQS and U.S. GHG data sets. Currently there is not a data set that gives emissions information specifically for the interstate transport of MSW or for the distance traveled. However the emission data can be estimated based on the data of the U.S. GHG data set which provides emissions information for diesel trucks.

The emission information for many of the pollutants produced by landfills, incinerators, and transportation are estimated or modeled values and may not be accurate. For instance, NAPET calculates projection pollutant data based on the model by using baseline data and the factors such as economic and population growths. Thus it is not purely scientific data. The distance traveled transporting MSW out-of-state is not recorded. Due to the lack of scientific data for some parameters and the potential for inaccuracies in estimated and modeled measurements, the following recommendations can be made:

- Monitor groundwater contamination at landfill sites to assess contamination by leachate;
- Monitor methane and carbon dioxide emissions directly from landfills;
- Compile emission data of the regulated pollutants specified under the Clean Air Act directly from incinerators; and,
- Obtain data of travel distances made by MSW transport to estimate approximate emission amounts.

These newly obtained indicators should be made available at a reasonable cost and be, theoretically, well founded in technical terms. These recommendations will allow for a better evaluation of the success of the Act.

Conclusion

The increasing generation of municipal solid waste, the closing of local landfills in favor of regional landfills, and the consolidation of the waste management industry have led to an increase in the amount of municipal solid waste crossing state lines for disposal. The transportation and disposal of waste to other states pose a number of environmental and health concerns for importing states, including air pollution and groundwater contamination and respiratory problems and cancer, respectively. These reasons, along with political and economical pressures, have prompted the submission of the Solid Waste Interstate Transportation Act of 2005 to the House of Representatives. This Act would allow states to limit the amount of imported municipal solid waste. It is difficult to project the impact of these limitations. The incentive to deal with waste locally may lead to innovation in disposal technologies, the use of existing alternative technologies, waste volume reduction, or a combination of these methods. However, the Act is not without drawbacks. States may simply choose to ship their waste to states that are willing to accept the waste. Some of the new waste treatment technologies are not as cost-effective as landfills and incinerators. Several of them require large amounts of land which can prove difficult in siting and many are still in the developmental stages. Exporting states may have to rely on a combination of these technologies and waste volume reduction in order to develop a self-sufficient and environmentally responsible waste management system.

In the fall semester, our Workshop Group will be analyzing the political and economic aspects of this legislation. We will also develop a management plan for implementing the program.

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