CHAPTER

5 Landfill Gas Control Measures

This chapter presents an overview of common landfill gas control technologies. These technologies include means to collect gases, control and treat gases, and use gases to benefit the community (e.g., to generate electricity or heat buildings). A landfill might need gas control measures for several reasons, including government regulations, odor problems, or uncontrolled releases of gases that could pose safety and health concerns. As an environmental health professional, you are not expected to be able to design and implement a landfill gas control plan. However, you should have a basic understanding of the control options that are available to help prevent or control exposures to landfill gas.

Why would control measures be implemented at a landfill?

Many landfills install gas control measures because of regulatory requirements. The federal government has developed laws and regulations that govern the operation and maintenance of landfills. These regulations have been developed to reduce health and environmental impacts from landfill gas emissions through the reduction of ozone precursors (volatile organic compounds and nitrogen oxides), methane, NMOCs, and odorous compounds. States may also have state-specific landfill regulations, which must be as strict or more strict than the federal regulations. The boxes on the next page review some of the applicable regulations.

As described in Chapter Three, odor complaints or potential safety and health concerns may also prompt landfill gas collection. Sulfide emissions are a common source of landfill odor complaints. At older landfills or at smaller landfills exempt from federal and state regulations, uncontrolled releases of landfill gases can pose potential safety and health concerns (e.g., explosion hazards). In such cases, the landfill might implement landfill gas control measures, even if they are not required by federal or state regulations. Some landfills have also implemented voluntary gas collection and control or treatment systems to recover landfill gas for energy production.

What are the components of a landfill gas control plan?

The goal of a landfill gas control plan is to prevent people from being exposed to landfill gas emissions. This goal can be achieved by either collecting and treating landfill gas at the landfill or by preventing landfill gas from entering buildings and homes in the community. Technologies used to control landfill gas at the landfill or in the community can be applied separately or in combination. Note that the NSPS/EG requires a gas collection and control system design plan for landfills that meet the criteria presented on the next page. The NSPS rule specifies the type of information that must be included and the criteria the collection and control systems must meet.

Federal Requirements Under Subtitle D of Resource Conservation and Recovery Act (RCRA) for Landfill Gas Migration Control

Since October 1979, federal regulations promulgated under Subtitle D of RCRA—which regulates the siting, design, construction, operation, monitoring, and closure of MSW landfills—have required controls on migration of methane in landfill gas. These regulations do not address other components of landfill gas. In 1991, EPA issued standards for landfill design and performance that apply to MSW landfills active on or after October 9, 1993. The standards require methane monitoring and establish performance standards for methane migration control. Monitoring requirements must be met at landfills not only during their operation, but also for a period of 30 years after closure.

Landfills affected by RCRA Subtitle D are required to control gas by establishing a program to periodically check for methane emissions and prevent off-site migration. Landfill owners and operators must ensure that the concentration of methane gas does not exceed:

- 25% of the LEL for methane in the facilities' structures (1.25% by volume)
- The LEL for methane at the facility boundary (5% by volume)

Permitted limits on methane levels reflect the fact that methane is explosive within the range of 5% to 15% concentration in air. If methane emissions exceed the permitted limits, corrective action (i.e., installation of a landfill gas collection system) must be taken. The Subtitle D RCRA regulations for MSW landfills can be found in 40 CFR Part 258, which can be viewed through EPA's Office of Solid Waste Web page at **http://www.access.gpo.gov/nara/cfr/cfrhtml_00/Title_40/40cfr258_00.html**

Federal Requirements Under the Clean Air Act (CAA) Regulations (NSPS/EG)

Under NSPS/EG of the CAA, EPA requires affected landfills to collect and control landfill gas. The NSPS/EG target reductions in the emissions of landfill gas due to odor, possible health effects, and safety concerns. The rules use NMOCs (which contribute to local smog formation) as a surrogate for total landfill gas to determine if control is required. Landfills meeting certain design capacity and emissions criteria are required to collect landfill gas and either flare it or use it for energy. Landfills that meet both of the following criteria must collect and control landfill gas emissions.

- Capacity: design capacity greater than or equal to 2.5 Mg and 2.5 million cubic meters.
- Emissions: annual NMOC emission rate greater than or equal to 50 Mg.

The basic requirements are the same for both existing and new landfills. Existing landfills are defined as landfills that received waste after November 8, 1987, and began construction before May 30, 1991. These are regulated through the EG. New landfills are defined as landfills that began construction, reconstruction, or modification on or after May 30, 1991. These are subject to the NSPS.

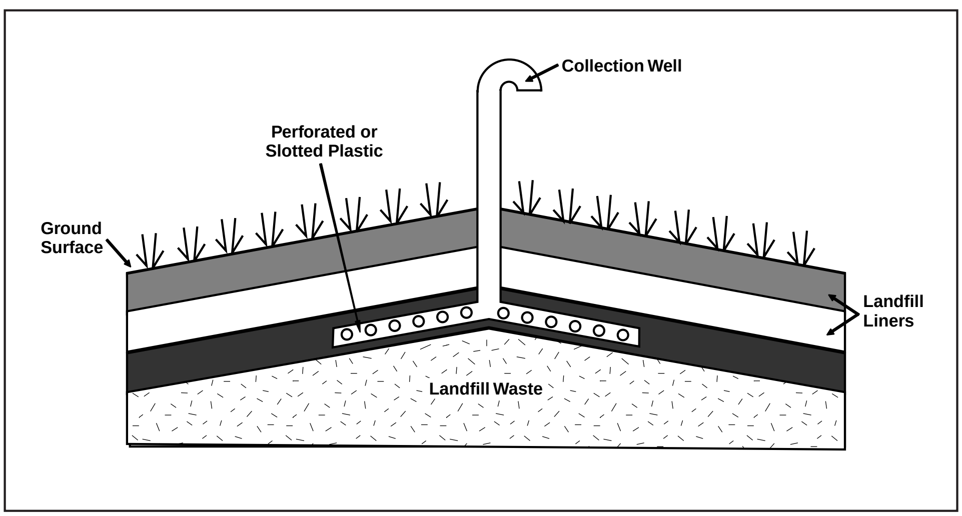
The CAA regulations (NSPS/EG) for MSW landfills can be found in 40 CFR Part 60, Subparts Cc and WWW, available on the Internet at **http://www.access.gpo.gov/nara/cfr/waisidx_00/40cfr60_00.html**. State plans and a federal plan to implement the EG for existing landfills can be found in 40 CFR Part 62. You can also view all Federal Register notices and summary information at **http://www.epa.gov/ttn/uatw/landfill/landflpg.html**.

How is landfill gas collected?

Landfill gas can be collected by either a passive or an active collection system. A typical collection system, either passive or active, is composed of a series of gas collection wells placed throughout the landfill. The number and spacing of the wells depend on landfill-specific characteristics, such as waste volume, density, depth, and area. As gas is generated in the landfill, the collection wells offer preferred pathways for gas migration, as discussed in Chapter Two. Most collection systems are designed with a degree of redundancy to ensure continued operation and protect against system failure. Redundancy in a system may include extra gas collection wells in case one well fails. The system-specific components for passive and active gas collection systems are discussed below.

- ***Passive Gas Collection Systems.*** Passive gas collection systems (Figure 5-1) use existing variations in landfill pressure and gas concentrations to vent landfill gas into the atmosphere or a control system. Passive collection systems can be installed during active operation of a landfill or after closure. Passive systems use collection wells, also referred to as extraction wells, to collect landfill gas. The collection wells are typically constructed of perforated or slotted plastic and are installed vertically throughout the landfill to depths ranging from 50% to 90% of the waste thickness. If groundwater is encountered within the waste, wells end at the groundwater table. Vertical wells are typically installed after the landfill, or a portion of a landfill, has been closed. A passive collection system may also include horizontal wells located below the ground surface to serve as conduits for gas movement within the landfill. Horizontal wells may be appropriate for landfills that need to recover gas promptly (e.g., landfills with subsurface gas migration problems), for deep landfills, or for active landfills. Sometimes, the collection wells vent directly to the atmosphere. Often, the collection wells convey the gas to treatment or control systems (e.g., flares).

Figure 5-1: Passive Gas Collection System



The efficiency of a passive collection system partly depends on how well the gas is contained within the landfill. Gas containment can be controlled and altered by the landfill collection system design. Gas can be contained by using liners on the top, sides, and bottom of the landfill. An impermeable liner (e.g., clay or geosynthetic membranes) will trap landfill gas and can be used to create preferred gas migration pathways. For example, installing an impermeable barrier at the top of a landfill will limit uncontrolled venting to the atmosphere by causing the gas to vent through collection wells rather than the cover.

The efficiency of a passive collection system also depends on environmental conditions, which may or may not be controlled by the system design. When the pressure in the landfill is inadequate to push the gas to the venting device or control device, passive systems fail to remove landfill gas effectively. High barometric pressure, as discussed in Chapter Two, sometimes results in outside air entering the landfill through passive vents that are not routing gas to control devices. For these reasons, passive collection systems are not considered reliable enough for use in areas with a high risk of gas migration, especially where methane can collect to explosive levels in buildings and confined spaces.

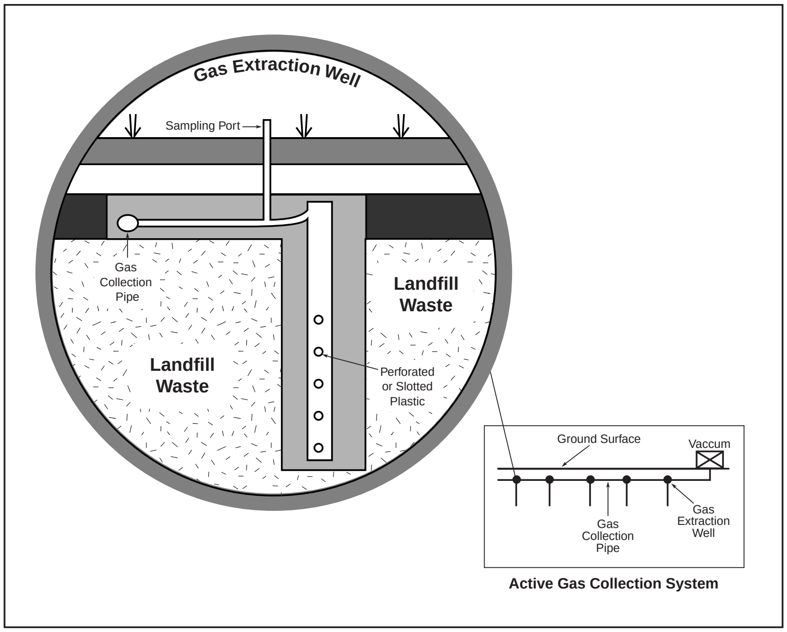
It is fairly common for landfills to flare gas due to odor concerns, for example, even if not the landfill is not subject to regulatory requirements. Passive gas collection systems may be used to comply with the NSPS/EG only at landfills where cells are lined in accordance with Subtitle D of RCRA to prevent gas migration.

Additional references on the effectiveness of passive systems can be found at: **http://www.dnr.state.mo.us/deq/swmp/fgtask7.htm** (Task 7-Gas Cut-Off Trench Effectiveness And Design) and **http://www.dnr.state.mo.us/deq/swmp/fgtask9.htm** (Task 9-Passive Vent To Active System Comparison).

- ***Active Gas Collection.*** Well-designed active collection systems (Figure 5-2) are considered the most effective means of landfill gas collection (EPA 1991). Active gas collection systems include vertical and horizontal gas collection wells similar to passive collection systems. Unlike the gas collection wells in a passive system, however, wells in the active system should have valves to regulate gas flow and to serve as a sampling port. Sampling allows the system operator to measure gas generation, composition, and pressure.

  Active gas collection systems include vacuums or pumps to move gas out of the landfill and piping that connects the collection wells to the vacuum. Vacuums or pumps pull gas from the landfill by creating low pressure within the gas collection wells. The low pressure in the wells creates a preferred migration pathway for the landfill gas. The size, type, and number of vacuums required in an active system to pull the gas from the landfill depend on the amount of gas being produced. With information about landfill gas generation, composition, and pressure, a landfill operator can assess gas production and distribution changes and modify the pumping system and collection well valves to most efficiently run an active gas collection system. The system design should account for future gas management needs, such as those associated with landfill expansion. The box on the next page describes components of an effective active gas collection system.

Figure 5-2: Active Gas Collection System



How Is an Effective Active Gas System Designed?

An effective active gas collection system incorporates the following design elements (EPA 1991):

- Gas-moving equipment, including vacuums and piping, capable of handling the maximum landfill gas generation rate.
- Collection wells placed to capture gas from all areas of the landfill. The number and spacing between each extraction well depends on the waste type, depth, and compaction; the pressure gradients created by the vacuums; and the moisture content of the gas.
- The ability to monitor and adjust flow from individual extraction wells. Inclusion of a valve, pressure gauge, condenser, and sampling port at each collection well allows a landfill operator to monitor and adjust pressure and to measure gas generation and content.

What methods are available to treat landfill gas after collection?

Some passive gas collection systems simply vent landfill gas to the atmosphere without any treatment before release. This may be appropriate if only a small quantity of gas is produced and no people live or work nearby. More commonly, however, the collected landfill gas is controlled and treated to reduce potential safety and health hazards. (A landfill may be required to do so by law, such as the NSPS/EG, as described in Chapter Four.) Common methods to treat landfill gas include combustion and noncombustion technologies, as well as odor control technologies.

- ***Combustion.*** Combustion is the most common technique for controlling and treating landfill gas. Combustion technologies such as flares, incinerators, boilers, gas turbines, and internal combustion engines thermally destroy the compounds in landfill gas. Over 98% destruction of organic compounds is typically achieved. Methane is converted to carbon dioxide, resulting in a large greenhouse gas impact reduction. Combustion or flaring is most efficient when the landfill gas contains at least 20% methane by volume. At this methane concentration, the landfill gas will readily form a combustible mixture with ambient air, so that only an ignition source is needed for operation. At landfills with less than 20% methane by volume, supplemental fuel (e.g., natural gas) is required to operate flares, greatly increasing operating costs. When combustion is used, two different types of flares can be chosen: open or enclosed flares.

— *Open flame flares* (e.g., candle or pipe flares), the simplest flaring technology, consist of a pipe through which the gas is pumped, a pilot light to spark the gas, and a means to regulate the gas flow. The simplicity of the design and operation of an open flame flare is an advantage of this technology. Disadvantages include inefficient combustion, aesthetic complaints, and monitoring difficulties. Sometimes, open flame flares are partially covered to hide the flame from view and improve monitoring accuracy.

— *Enclosed flame flares* are more complex and expensive than open flame flares. Nevertheless, most flares designed today are enclosed, because this design eliminates some of the disadvantages associated with open flame flares. Enclosed flame flares consist of multiple burners enclosed within fire-resistant walls that extend above the flame. Unlike open flame flares, the amount of gas and air entering an enclosed flame flare can be controlled, making combustion more reliable and more efficient.

— *Other enclosed combustion technologies* such as boilers, process heaters, gas turbines, and internal combustion engines can be used not only to efficiently destroy organic compounds in landfill gas, but also to generate useful energy or electricity, as described later in this chapter.

Some public concerns have been raised about whether the combustion of landfill gas may create toxic chemicals. Combustion can create acid gases such as SO_2 and NO_X. The generation of dioxins has also been questioned. EPA investigated the issue of dioxin formation and concluded that the existing data from several landfills did not provide evidence showing significant dioxin formation during landfill gas combustion. Because of the potential imminent health threat from other components of landfill gas, landfill gas destruction in a properly designed and operated control device, such as a flare or energy recovery unit, is preferable to uncontrolled release of landfill gas. Scientists continue to review new information on by-product emissions from landfill gas control devices as it becomes available.

- ***Noncombustion.*** Noncombustion technologies were developed in the 1990s as an alternative to combustion, which produces compounds that contribute to smog, including nitrogen oxides, sulfur oxides, carbon monoxide, and particulate matter. Noncombustion technologies fall into two groups: energy recovery technologies and gas-to-product conversion technologies. Regardless of which noncombustion technology is used, the landfill gas must first undergo pretreatment to remove impurities such as water, NMOCs, and carbon dioxide. Numerous pretreatment methods are available to address the impurities of concern for a specific landfill. After pretreatment, the purified landfill gas is treated by noncombustion technology options.

— *Energy recovery technologies* use landfill gas to produce energy directly. Currently, the phosphoric acid fuel cell (PAFC) is the only commercially available noncombustion energy recovery technology. Other types of fuel cells (molten carbonate, solid oxide, and solid polymer) are still under development. The PAFC system consists of landfill gas collection and pretreatment, a fuel cell processing system, fuel cell stacks, and a power conditioning system. Several chemical reactions occur within this system to create water, electricity, heat, and waste gases. The waste gases are destroyed in a flare.

— *Gas-to-product conversion technologies* focus on converting landfill gas into commercial products, such as compressed natural gas, methanol, purified carbon dioxide and methane, or liquefied natural gas. The processes used to produce each of these products varies, but each includes landfill gas collection, pretreatment, and chemical reactions and/or purification techniques. Some of the processes use flares to destroy gaseous wastes.

- ***Odor Control Technologies.*** Odor control technologies prevent odor-causing gases from leaving the landfill. Installing a *landfill cover* will prevent odors from newly deposited waste or from gases produced during bacterial decomposition. Covering a landfill daily with soil can help reduce odors from newly deposited wastes. More extensive covers are installed at landfill closure to prevent moisture from infiltrating the refuse and encouraging bacterial growth and decomposition. Vegetative growth on the landfill cover also reduces odors. *Flaring* is another technique that can eliminate landfill gas odors by thermally destroying the odor-causing gases. *Venting* landfill gas through a filter is another technology used to reduce odors. Landfill gas is collected and vented through a filter of bacterial slime. As long as oxygen is present, bacteria will decompose landfill gas under aerobic conditions, producing carbon dioxide and water. See the example below of odor controls used at a landfill in California.

Odor Control at the Calabasas Landfill

The Calabasas Landfill, serving 1.4 million people in the Los Angeles area, received approximately 17 million tons of waste from its inception in 1961 through December 1995, when the County of Los Angeles passed an ordinance limiting its use.

Beginning in the mid-1980s, an active landfill gas collection system was installed in phases. The system consists of a network of vertical wells and horizontal trenches placed throughout the refuse fill. A vacuum is applied to the system of wells and trenches to draw the gas into the collection system. The collected gas is routed to a flare station and combusted in flares.

The gas collection system, along with rejection of odorous loads and application of daily cover, is a primary means of controlling odor at the landfill. As a result of these measures, the facility received only one odor complaint during 1995 (NPS 1997).

What methods are available to control landfill gas if it reaches nearby structures?

Under certain conditions, landfill gas migrating underground from the landfill to the surrounding community could present safety and health hazards, such as explosion or asphyxiation hazards. (see Chapter Three for a more detailed discussion of these hazards.) Once landfill gas reaches a building or home, it can enter the structure through a number of available pathways (as shown in Chapter Three, Figure 3-1).

To prevent landfill gas from entering buildings, controlling the gas at the source (the landfill) is the preferred approach. However, several simple community-based or structure-based controls are available to reduce the gas entry pathways and limit indoor migration of gas. If a landfill gas problem is anticipated before construction, control strategies can be incorporated into the building design. If not, alterations to the finished structure might be needed. The two basic approaches to preventing gases from entering a structure include controlling the gas pressure and eliminating available entry pathways or leaks. Regardless of the methods used to prevent or reduce landfill gas entry, continuous methane monitors with appropriate alarms should be strategically placed in buildings where accumulation of explosive levels of landfills gases is possible. The methane monitors and engineering controls should have a frequent safety check and maintenance program to ensure proper function. The box below details the limitations of different landfill gas control options.

- ***Gas Pressure Controls.*** If gas pressure is lower inside a building or structure than it is in the surrounding soils, gas will flow into the building or structure. Controlling gas pressure, therefore, can prevent gas migration indoors. Some techniques to control gas pressure include passive or active venting to reduce gas concentrations under the house, venting around the perimeter of the house, and crawl-space venting. Some of these techniques, however, may require pumps with maintenance and energy requirements.
- ***Leakage Area Controls.*** Another strategy to prevent gas from entering a building or structure is to reduce or eliminate entry pathways. Gas can leak into a building or structure through cracks, gaps, drainage pipes, fireplace air vents, and air conditioning or duct work. Improving plumbing and caulking in a basement to reduce cracks and gaps will reduce entry pathways. These options, however, may only partially address indoor

What Are the Limitations of the Landfill Gas Control Options?

Landfill Gas Collection Technologies

Active venting

- Effectiveness depends on proper placement of system to gas source.
- Improper operation and monitoring potentially creates aerobic conditions that may lead to piping deformation and subsurface fires.
- Requires monitoring and maintenance.

Passive venting

- Most effective using shallow trenches.
- Not completely effective for petroleum-based vapors.

Community Control Technologies

Gas Pressure Controls

- Crawl space venting requires maintenance, and performance data are limited.
- Passive venting is effective only with low underground gas concentrations.
- Active venting may require maintenance.

Leakage Area Controls

- Plumbing corrections may only partially remedy the problem.
- Use of sealing, caulking, and liners has had limited success.

gas migration. Another control option is to install a low-permeability liner around the basement or underground portion of the building.

Are there any beneficial uses for collected landfill gas?

Landfill gas is the single largest source of man-made methane emissions in the United States, contributing to almost 40% of methane emissions each year (EPA 1996). Consequently, a growing trend at landfills across the country is to use recovered methane gas from landfills as an energy source. Collecting landfill gas for energy use greatly reduces the risk of explosions, provides financial benefits for the community, conserves other energy resources, and potentially reduces the risk of global climate change.

Currently in the United States, approximately 325 landfill gas energy recovery projects prevent emissions of over 150 billion cubic feet of methane per year (or more than 300 billion cubic feet of landfill gas). Approximately 220 of these projects generate electricity, producing a total of more than 900 megawatts per year. Another 68 projects are under construction in 2001, and more than 150 additional projects are in the planning stages. Previous studies by EPA and the Electric Power Research Institute estimate that up to 750 of the landfills in the United States could profitably recover and use their methane emissions (DOE n.d.a.).

What landfills can be used for gas recovery and how is energy generated from landfill gas?

The feasibility of installing a landfill gas recovery system depends on factors such as landfill gas generation rates, the availability of users, and the potential environmental impacts. Many different landfill types with varying gas production rates and composition can support energy recovery projects. There are, however, several guidelines to consider when assessing the feasibility of generating energy from landfill gas. The box on the following page lists some of these guidelines.

If feasible, energy recovery can be implemented by use of combustion- or noncombustion-based technologies. Combustion-based technologies that recover energy include boilers, process heaters, gas turbines, and internal combustion engines. For example, landfill gas can be piped to a nearby industry, commercial business, school or government building where it is combusted in a boiler to provide steam for an industrial process or heat for a building. It may be combusted in an industrial process heater to provide heat for a chemical reaction. Turbines and internal combustion engines can combust landfill gas to generate electricity. The electricity can be used to meet power needs at the landfill or a nearby facility, or the electricity may be sold to the power grid.

The choice of which type of combustion device to use (e.g., boiler, gas turbine, internal combustion engine) depends on what users are located near the landfill, site-specific technical and economic considerations, and sometimes environmental impacts. For example, internal combustion engines are often less costly than gas turbines for smaller landfills. However, these engines may emit more NO_X, which contributes to ozone formation. If the landfill is in a nonattainment area for ozone, then NO_X emissions may be a barrier to using an internal combustion engine.

Information on typical emissions from various combustion devices can be found in EPA's compilation of air pollutant emission factors (AP-42). Information on these technologies can also be found in the background document for the NSPS/EG (EPA 1991) and on the Landfill Methane Outreach Program (LMOP) Web site at **http://www.epa.gov/lmop**.

What Are Some Factors Important For Landfill Gas Recovery?

Landfill gas recovery systems cite the following factors as guidelines important for economically feasible landfill gas recovery projects. However, new technologies are becoming available that have allowed successful projects at smaller landfills. For example, smaller landfills can generate enough gas to heat an on-site greenhouse or to use a microturbine to generate a small amount of electricity. Various federal and state incentives (e.g., grants, loans, tax credits, renewable energy purchase requirements) can also enhance the economic feasibility of landfill gas recovery projects.

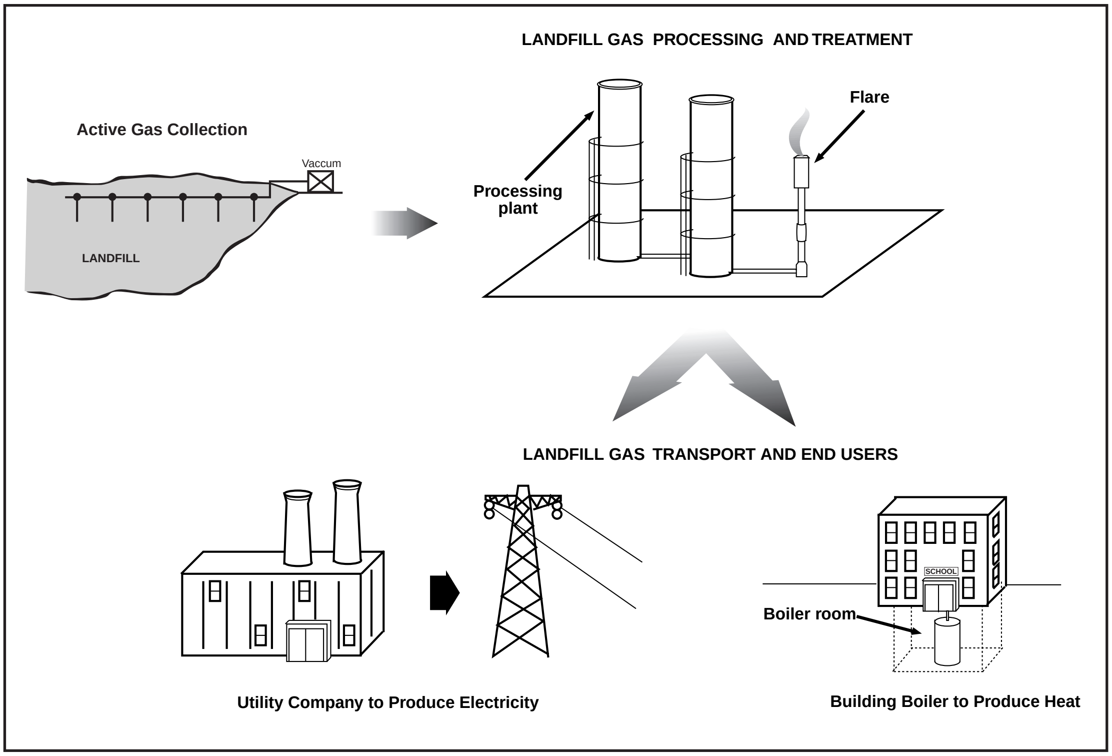
- The amount of waste in place at a landfill is greater than approximately 1 million tons.
- The waste is greater than 35 feet deep and is stable enough for well installation.
- The landfill area is greater than 35 acres.
- The landfill is composed of refuse that can generate large quantities of landfill gas composed of 35% or more of methane. An industry guideline states that gas recovery is economically viable at landfills with gas generation rates of 1 million cubic feet per day (EPA 1996).
- If a landfill is still open, active landfill operation will continue for several more years.
- If a landfill is already closed, a short time (no more than a few years) has elapsed since closure.
- The climate is conducive to gas production (very cold or very dry climates can inhibit gas production).
- The energy user is located nearby or in an area accessible to the landfill.

Noncombustion energy recovery systems are also available, but are not used as widely. Fuel cells are a promising new technology for producing energy from landfill gas that does not involve combustion. This technology has been demonstrated and in the future may become more economically competitive with other options. One option that does not involve combustion of landfill gas at or near the landfill is purifying the landfill gas to remove constituents other than methane, producing a high British thermal unit (Btu) gas that can be sold as pipeline quality natural gas. While the high Btu gas is eventually combusted, it would not contribute to any emissions near the landfill. Another option is using compressed landfill gas as a vehicle fuel.

Both combustion and noncombustion energy recovery systems have three basic components: (1) a gas collection system; (2) a gas processing, treatment, and conversion system; and (3) a means to transport the gas or final product to the user (Figure 5-3). Gas is collected from the landfill by the use of active vents. It is then transported to a central point for processing. Processing requirements vary, depending on the gas composition and the intended use, but typically include a series of chemical reactions or filters to remove impurities. For direct use of landfill gas in boilers, minimal treatment is required. For landfill gas injection into a natural gas pipeline, extensive treatment is necessary to remove carbon dioxide. At a minimum, the gas is filtered to remove any particles and water that may be suspended in the gas stream.

Some examples of successful landfill gas to energy projects are presented in the box on page 63. For more information about landfill gas-to-energy projects, visit the EPA's Landfill Methane Outreach Program (LMOP) Web site at **http://www.epa.gov/lmop**.

Figure 5-3: Landfill Gas Recovery System



Reusing Landfill Gas: Success Stories

Below are some examples of how gas collected from landfills is being reused for power.

- In Raleigh, North Carolina, Ajinomoto Pharmaceutical Company has used landfill gas as fuel in boilers at its facility since 1989. The steam produced by the boilers is used to heat the facility and warm pharmaceutical cultures. This project has prevented pollution equivalent to removing more than 23,000 cars from the road.
- In Pittsburgh, Pennsylvania, Lucent Technologies saves $100,000 a year on fuel bills by using landfill gas to generate steam for space heating and hot water.
- The City of Riverview, Michigan, works with the local utility, Detroit Energy, to recover landfill gas and create electricity with two gas turbines. The project generates enough power to meet the energy needs of more than 3,700 homes.
- The Los Angeles County Sanitation District in California has succeeded in turning landfill gas into a clean alternative vehicle fuel. Landfill gas is compressed to produce enough fuel per day to run an 11-vehicle fleet, ranging from passenger vans to large on-road tractors.
- Pattonville High School in Maryland Heights, Missouri, is located within 1 mile of a municipal solid waste landfill. The landfill supplies methane gas to heat the 4,000-square-foot high school, saving the Pattonville School District thousands of dollars in annual heating costs. Pattonville High School was the first high school to use landfill gas as its source of heat (CNN 1997)

Additional Resources

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