Renewable Energy Technologies at Superfund Sites

The goal of Cleanup—Clean Air is to encourage, facilitate, and support diesel emissions and greenhouse gas reductions technologies and practices at Superfund cleanup and redevelopment sites.

What is Renewable Energy?

Renewable energy is obtained from sources that are essentially inexhaustible (e.g., solar, wind, biomass). While fossil fuels are being depleted, renewable energy technologies provide a lasting source of energy. This document includes information on solar, wind, landfill gas and biomass. One use of renewable energy is to generate heat and electricity to power Superfund cleanup sites. Using renewable energy can avoid many of the pollutants that are emitted from fossil fuel use as well as reduce the demand to extract fossil fuels.

Purpose of Cleanup – Clean Air

The Cleanup-Clean Air Initiative (CCA) is focused on encouraging, facilitating and supporting implementation of diesel emissions and greenhouse gas reductions technologies and practices at Superfund cleanup and redevelopment sites. To accomplish the greenhouse gas reduction goal, Cleanup – Clean Air:

→ Raises awareness of the potential for greenhouse gas emissions reductions at Superfund cleanup and redevelopment sites;

→ Provides coordination and facilitation support for potential Cleanup-Clean Air projects;

→ Creates a forum for information sharing among renewable energy users, and works to leverage significant new resources to expand voluntary greenhouse gas reduction; and

→ Creates momentum for future greenhouse gas reduction efforts within the Superfund Program and elsewhere.

CCA Website www.epa.gov/region9/cleanup-clean-air
♦ Cleanup-Clean Air Pilot Projects ♦ Smart Energy Resources Guide ♦ Factsheets ♦ Cleanup-Clean Air Updates ♦ Cleanup-Clean Air Staff Contact Info

Importance of Using Renewable Energy

Most electricity is generated from coal combustion, which releases greenhouse gases (GHGs) and criteria air pollutants into our atmosphere that harm the environment and human health. In 2005, more than 2.6 billion metric tons of CO_2 were emitted from electricity production in the US.[1] So, on average, in 2005, the nation generated about 8.7 metric tons of CO_2 per person due to electricity production. To estimate the emissions reductions from using renewable energy at your cleanup site, go to:

www.epa.gov/cleanenergy/energy-and-you/how-clean.html

There is much interest in increasing renewable energy use and reducing greenhouse gases at the executive level by way of provisions in the Energy Policy Act of 2005, Executive Order 13123 (Greening the Government through Efficient Energy Management), Executive Order 13432 (concerning greenhouse gases from vehicles and engines), and EPA clean energy and climate priorities.

Renewable Energy Options

Solar panels can provide a large amount of energy to run site equipment. Cost: $8,000-$10,000 per kW.[2]

Wind turbines harness wind energy. A single medium-sized wind turbine with good wind conditions can provide enough energy for eight 3-bedroom homes. Cost: $2,000-$7,000 per kW.[3]

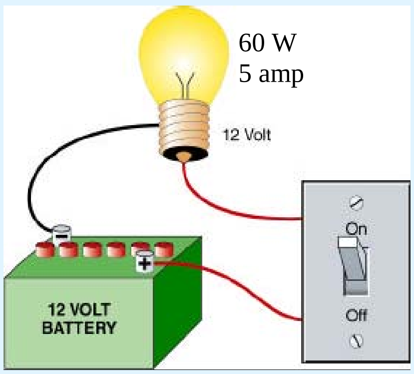
Landfill-gas-to-energy projects collect biogas which is naturally produced by landfills as the waste degrades. Energy from biogas can be converted into electricity for site use. Costs vary; See page 14.

Anaerobic digesters decompose organic wastes in a controlled environment to produce biogas which can be used to generate electricity. Cost: ~ $3,500 per kW.[4]

Energy Refresher

Here are some common energy terms to be familiar with to better understand how renewable energy projects can be implemented at your site. Energy is the ability of a system to do work. Forms of energy include chemical, thermal, radiant, mechanical and electrical energy. The following is basic information about how electrical energy works.

Understanding Electricity Using a Hydraulic Analogy



Electric circuit. Image courtesy Solar on-Line[5]

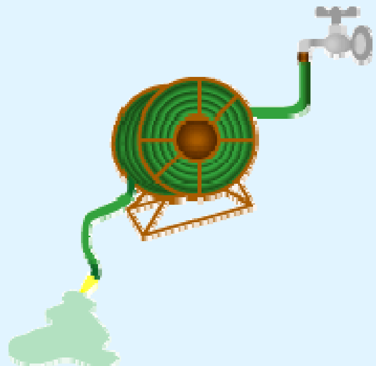


Image courtesy NDT[6]

Think of a faucet with a hose to help understand amps, voltage, and watts. Electricity running through a wire is analogous to water running through a hose.

Voltage: Voltage is the "pressure" that pushes electrons along in a wire. This "electrical pressure" is analogous to water pressure in a garden hose. The greater the pressure, the more energy each parcel of water has in the hose and the greater the force with which it is pushed along.[7] Voltage is measured in **volts**, usually abbreviated "**V**".

Amperes (Amps): An ampere is a unit of measure of electrical current. An electrical current is the rate at which electrons flow past a certain point in a wire. This electrical flow rate is analogous to a volume of water flowing per second. Amperes is usually abbreviated "**amps**" or "**I**".[8]

Power (Watts): The rate at which electricity is produced or consumed is referred to as power. It measures how much energy is needed to start a device or operate a piece of equipment per unit time. Using the water analogy, power is the combination of water pressure (**voltage**) and rate of flow (**current**) that allows work to be done (e.g., lighting a light bulb, water turning a turbine). Power is measured in **watts (W)** and can also be measured in **horsepower** (**hp**). One hp is equivalent to 745.7 W. The power rating is usually found on the specs of a piece of equipment.

Power (watts) = voltage (volts) x current (amps)

The actual energy used is measured in **watt-hours (Wh)**. Therefore, a 60-watt light bulb needs 60 watts of power to operate. If it operates for 3 hours, this light bulb will use 60 W x 3 hr = 180 Wh of energy.

Electrical Energy (Wh) = Power (W) x Time Operated (hours)

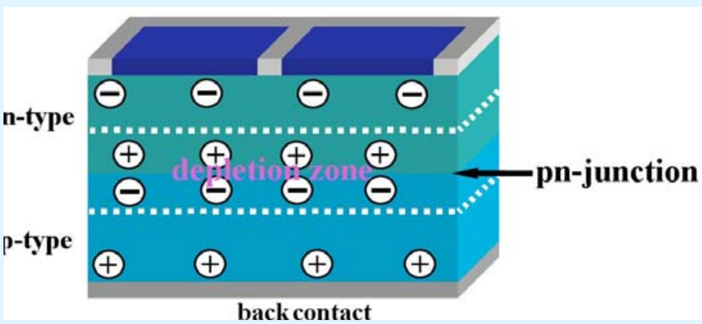
You most often see **kWh** on an energy bill and it stands for **kilowatt-hours**. One kilowatt is 1,000 watts. A **megawatt** (**MW**) is 10^6 watts and a **gigawatt** (**GW**) is 10^9 watts. A typical 3 bedroom house will use about 600 kWh per month.[9] Another energy unit, the **British Thermal Unit** (**BTU**), is usually used to describe the energy content in fuels like natural gas. One kWh is equivalent to 3,414 BTUs.

Alternating and Direct Current: Electricity needs a complete circuit to flow. Electricity flowing in one direction is referred to as **Direct Current (DC)**, like in batteries and solar modules. Electricity that cyclically reverses direction is referred to as **Alternating Current (AC)**. Most appliances and equipment use this type of power. and utility companies provide power as AC. Some renewable energy sources such as solar power and small wind turbines generate electricity as DC and an inverter is used to convert it to usable AC power.[10]

Solar Power

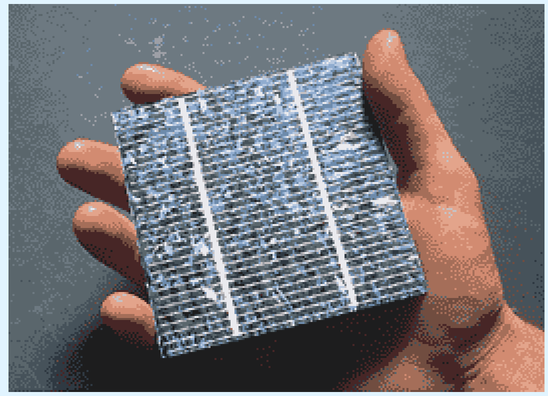
Solar Power Basics

Energy from the sun's radiation can be converted directly to electricity. **Photovoltaic** (**PV**) technology produces electricity from sunlight. Sunlight photons hit PV cells and create an electrical current. PV systems generate electricity without noise or pollution (although the production of PV systems results in some emissions) and are widely available. PV systems last about 25 years, at which time the unit produces power at around 80% of its original power rating. PV technology can be installed almost anywhere and typically requires little maintenance, depending on the complexity of the system.



The pn-junction of a solar PV cell. Image courtesy Special Materials and Research Technology[11]

The core component of a solar panel is a PV cell. Individual PV cells wired together in a sealed unit are called a **module**. Modules wired together are called an **array**. PV cells are composed of at least two layers of semiconductor material, commonly silicon-based. Photons (discrete packets of light) striking the cell release electrons from the negative layer and they flow towards the positive layer, creating an electrical current. A metal wire placed on the positive and negative sides powers a load with the induced current. The electrons flow in a single direction, generating direct current (DC). Most readily available PV systems are crystalline modules that are around 10%-15% efficient. **Single-crystalline** solar cells are made from a single large crystal. **Multi-crystalline** modules are made from multiple crystals grown together and are slightly less efficient than single-crystal modules. **Amorphous** modules, or thin film technology, are manufactured by depositing semi-conductor material onto a sheet of glass or plastic. They have maximum efficiencies of around 10%. These are ideal for building integrated uses such as roof tiles or shingles (see image on page 6).



Multi-crystalline solar cell. Image courtesy Lawton Ltd[12]

Sizing a PV System for My Site

The size of the PV system depends on the energy demands and available solar energy at a particular site. PV modules have two efficiency ratings. One measure is the Standard Test Conditions Rating set by the manufacturer which represents the maximum output in laboratory conditions. The more applicable efficiency rating is the PV-USA Test Conditions rating which reflects the electricity output under day-to-day conditions. In general, a 1-kW PV system in Region 9 territory will produce between 135 and 150 kWh per month. As a rule of thumb, a 1-kW system requires at least 100 ft^2 of space for crystalline systems. Amorphous cells would need about 150 ft^2 per kW.[13] Use the following equations to get approximate figures for the size and cost of a simple stationary, or fixed tilt, PV system for your site. Note that these equations do not account for batteries or solar tracking capabilities.

Size of PV System		Site Energy Needs per Month		Average PV Energy Output
? kW	=	___kWh per month	÷	135 kWh per month per kW

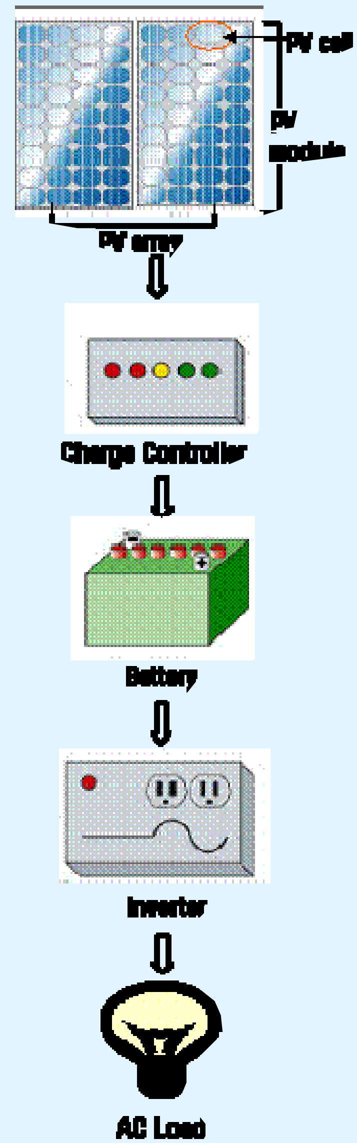
Total Cost of PV System		Size of PV System		PV System Price per kW
? $	=	___kW	x	$10,000 per kW

Here are a few websites that can help you size a PV system for the electricity needs at your site:

- This site is hosted by solar professional organizations and the U.S. Department of Energy (DOE). www.findsolar.com/index.php?page=rightforme
- This calculator was developed by DOE National Renewable Energy Laboratory (NREL) researchers. www.pvwatts.org

Solar Power

PV System Terminology



Typical PV system configuration. Separate images courtesy Solar on-Line except "AC Load"[14]

PV Cell — A PV cell is the core component of a solar module that converts sunlight into electricity.

PV Module — PV modules are made up of individual PV cells wired together.

PV Array — A PV array is composed of one or more PV modules wired together.

Charge Controller — A charge controller is a device that prevents PV panels from overcharging the batteries and the batteries from overly discharging electricity.

Battery — Batteries can store electricity to be used during periods without sunlight or augment peak loads during the day.

Inverter — An inverter changes direct current (DC) to alternating current (AC). Electricity produced by the PV system is DC and stored as DC if batteries are included in the PV system but appliances and equipment usually use AC power.

Load — A load is the general term for the power demanded by any device, equipment, or appliance that consumes electricity.

Balance of System — The balance of system includes all other hardware including wiring and safety equipment that keep the system functional.

Grid-tied — Grid-tied systems have access to electricity supplied by a utility. These systems can receive energy produced from a local PV system as well as from the utility and do not require battery back-up. Energy from solar panels that is not used immediately at the site can be sent to the energy grid. When solar power is not being produced, such as at night, the site can use electricity provided from the utility. For net metered systems, the utility acts like a giant battery. Sites that do not have access to grid-electricity will have to completely rely on an alternate power source. If it is important to have a constant electricity source, battery backup is necessary.

Net Metering — Net metering programs allow grid-tied utility customers who generate electricity in excess of their consumption at a certain time to credit that amount for later use. www.eere.energy.gov/greenpower/markets/netmetering.shtml

Crystalline vs Amorphous Modules — Crystalline modules are currently the most efficient modules. They are delicate and need to be mounted on a rigid frame. Amorphous modules are currently less efficient but advancing technologies show that they may soon produce electricity at rates almost as high as single-crystal modules. Amorphous modules are flexible, and efficiency is not as affected as crystalline varieties by high temperatures, shading or cloudy days. They are also used in building-integrated PV applications such as in roof tiles (see image on page 6).[15]

Tracking or Fixed Tilt — Tracking units point PV arrays at the optimal angle to the sun throughout the day. They can increase efficiency by 15% in the winter and 40% in the summer and thus reduce the size of the system but require significant additional costs. They may need more frequent maintenance due to the moving parts. They are best used at sites with long hours of sunlight and with no shading. Fixed tilt units do not move; they are tilted at an angle equal to the latitude of the site to capture the greatest amount of energy over the year without using a tracking system.

Solar Power

Does My Site Have Good Potential for Solar Power?

Sites that receive direct sunlight without shading from the hours of 9am to 3pm have good solar power potential. For crystalline systems, completely shading just one cell can reduce efficiency by 75%.[16] On moderately cloudy days, arrays can produce 80% of electricity compared to a bright sunny day. Ideally, panels (for sites in the northern hemisphere) should be south-facing for maximum sunlight exposure. Each kW of solar panels needs at least 100 ft^2 of space. Panels can be mounted on roofs or poles or directly on the ground. The following NREL website provides maps of sunlight availability based on location and type of solar mounting (fixed tilt or tracking).

http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/atlas/

Keep in mind that this website gives the actual solar radiation hitting earth's surface. Solar modules are 10%-15% efficient at capturing this energy. PV panels can provide power to Superfund site remediation systems (1) that are off-grid; (2) that utilize low-flow pump systems; and (3) to augment grid-power for sites with high electricity demand. In general, PV systems will be most suitable for sites with an expected long-term need for power to operate equipment.

Solar Tracking Unit. Image courtesy Northern Arizona Wind and Sun[17]

Operation and Maintenance

Panels should be cleaned once a year if the site receives little rain and/or wind. See the PV equipment manual for more information on maintenance of the system and its components. Inverters usually need replacement after about 15 years of operation. Cost for inverter replacement is about $700/kW.[18] Annual maintenance cost is 0.25%-1.5% of initial system cost.

Cost

A system with battery backup costs $15-$20 per rated watt ($15,000-$20,000 per kW). PV systems without batteries cost $8-$10 per rated watt ($8,000-$10,000 per kW).[19] Use the following calculators to estimate costs, cash flow, and energy production:

www.findsolar.com (select "My Solar Estimator")

www.consumerenergycenter.org/renewables/estimator

Funding Resources

Federal Investment Tax Credit

Residential and commercial sectors are eligible for this rebate. For equipment installed before Dec. 31, 2008, the rebate is 30% of the capital cost. Equipment installed after January 1, 2009 will get a 10% rebate. Residential rebates have a $2,000 cap. There is no cap for businesses. PRP-lead sites are eligible while EPA-lead sites may not be. www.irs.gov/pub/irs-pdf/f3468.pdf

California Solar Initiative

The California Public Utilities Commission provides over $2 billion in incentives over the next decade for existing residential homes and existing and new business, industrial, agricultural, and non-taxable properties. The California Energy Commission has $350 million for its New Solar Homes Partnership. Customers of PG&E, SCE, and SDG&E are eligible. This incentive may be applicable to Superfund and redevelopment sites. For more information go to www.gosolarcalifornia.ca.gov.

Search for state and local incentives at **www.dsireusa.org**.

Considerations

- Panels should be cleaned more frequently for sites located in dusty regions and in areas with bird populations.
- Inverters should be stored in a cool and dry location out of direct sunlight if possible. Dust and cobwebs on the inverter unit inhibit it from cooling properly.
- A module will lose approximately 0.5% efficiency per degree centigrade temperature rise between 80˚C and 90˚C. It is important to allow air flow under and over the modules to remove heat and avoid high cell temperatures.[20]
- A module degrades about 0.5% per year in efficiency.[21]
- Some efficiency is lost from the inverter, battery and wiring.

Solar Power

Permits

Installers are usually responsible for garnering permits from city and/or county offices and will pass on the costs to the consumer. Among these are building permits and electrical permits. Permit fees may cost up to $1,500 although some cities have eliminated the fee for solar installations. Sometimes, additional drawings or calculations must be provided to the permitting agency. Be sure the permitting costs and responsibilities are addressed with your PV contractor before installation begins.

Hybrid solar and wind system. Image courtesy DOE[23]

Building integrated PV. Image courtesy Kyocera[22]

Choosing a Solar Installer

Setting up a PV system on a cleanup site is usually done through a solar installer or contractor. They will design and size the PV system, and acquire and install the appropriate panels, inverters, batteries, mounting, and any other equipment, for a full running system. Here are a few websites that provide a variety of information on solar installers:

- Pre-screened, customer reviewed installers: www.findsolar.com
- National solar trade association: www.seia.org/members.php
- General Services Administration Contracts Schedule: www.gsaelibrary.gsa.gov
  Search "206 3" for solar businesses
- Renewable energy businesses and organizations directory: www.energy.sourceguides.com

For More Information

Solar resources for businesses:

www.nrel.gov/learning/sb_photovoltaics.html

For technical PV information:

www1.eere.energy.gov/solar/photovoltaics.html

Finding the Right Solar Contractor

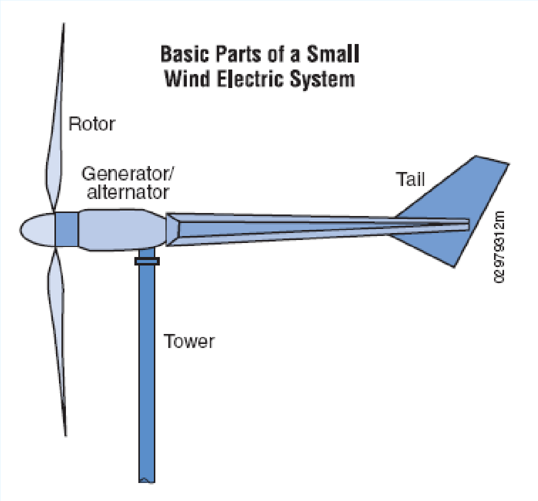
Start with contractors local to the site since they would be familiar with the weather, sun availability, and permitting processes of the area. Make sure that they are licensed. Research or interview the companies. Some key questions to ask are:

- How many years have they been in business?
- How many projects did they complete in the past year?
- Can they provide references for past projects similar to the one for the cleanup site?
- Have their installers been trained in PV projects?
- What warrantees or guarantees are included?
- Do they offer a wide variety of products? (manufacturers of panels, batteries, inverters, etc.)
- Do they offer services after the PV system is installed? If so, for how long?
- Are they a member of a trade organization?
- Ask for a cost estimate
  - Do they include the type of mounting requested, type of solar PV, etc? Ask for peak and average kW output estimates for specific conditions and seasons (sunny, summer, etc.) to be included in the bid. For battery systems, ask for specifications on battery capacity, recharging times, and the recharging cycle that will be used. Cheaper estimates may not include a service or device or may have hidden costs.

Wind Power

Wind Power Basics

Wind results from the uneven heating of the earth's surface and atmosphere, rotation of the earth, and topographical irregularities.[24] Kinetic energy in wind can be captured by wind turbines and converted to mechanical energy. Generators produce electricity from this mechanical energy. Simply, wind turbines work like a fan operating backwards. Instead of electricity making the blades turn to blow wind from a fan, wind turns the blades of a turbine to generate electricity.



Basic parts of a wind turbine. Image courtesy DOE EERE[25]

Wind turbines range in size from a few kilowatts to as large as several megawatts. The amount of power produced by the turbine depends on the length of the blades and the speed of the wind. The faster the wind speed, the more kinetic power it has. There is a cubic relationship between wind speed and power, which means that a small change in wind speed will have a large effect on power produced. Wind speeds vary with height and are generally weaker near the ground due to friction between earth's surface and air flow. To reduce turbulence and capture a greater amount of wind energy, turbines are mounted on towers. A common tower height is about 150 feet, though it will depend on the length of the blades. A 10-kW turbine will usually need a tower of 80-120 feet.[26] Wind speeds are classified into wind power classes designated Class 1 (lowest) through Class 7 (highest). Sites with Class 2 and above wind speeds (at least **10 mph measured at 33 feet above ground**) could consider installing a small wind turbine. See page 9 for wind speed maps.

Close-up of wind turbine. Image courtesy Argonne National Lab[27]

There are two basic groups of wind turbines. Horizontal axis turbines (propeller style) have two blades that face downwind or three blades that face upwind. Vertical axis turbines, such as the eggbeater-style Darrieus model, are less commonly used. Blades for both types are made from fiberglass, carbon fiber, carbon composites, or wood and will not interfere with TV or radio waves.[28] Wind turbines can be used in a wide variety of applications from charging batteries, to pumping water, to powering a significant portion of a site. Turbines may produce DC or AC power depending on the generator. Generators that produce DC power need an inverter to change the power to AC for use in most equipment. Some efficiency is lost through the inverter. A 1.5-kW wind turbine will produce about 300 kWh per month in a location with a 14 mph (6.26 meters-per-second) annual average wind speed. The turbine manufacturer can provide the expected energy output of a turbine for wind conditions at your site.

Darrieus model wind turbine. Image courtesy Solcomhouse[29]

Wind Power

Wind Turbine Terminology

Anemometer — Device on a wind turbine that measures the wind speed and transmits wind speed data to the controller.

Blades — Most turbines have either two or three blades.

Controller — Component of a turbine that starts up the rotor in wind speeds of about 8-16 mph and shuts it off when wind speeds exceed about 65 mph. Usually, turbines cannot operate in such high wind speeds because their generators could overheat.

Cut-in speed — Minimum wind speed needed to turn the blades and produce electricity. Varies from turbine to turbine.

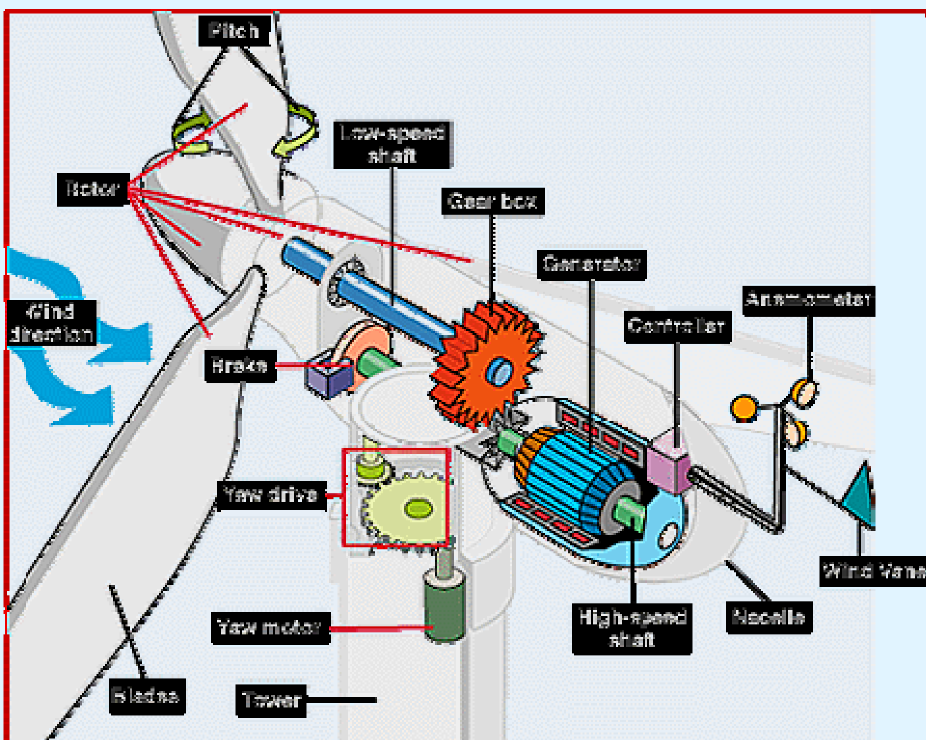
Cut-out speed — Maximum wind speed that a turbine can handle. Turbines automatically stop spinning at winds greater than the cut-out speed to prevent damage to the turbine. Varies from turbine to turbine.

Generator — Device that converts mechanical energy into electrical energy.

High-speed shafts — Drive the generator at 1,000-1,800 revolutions per minute (rpm).

Low-speed shafts — Drives the generator at 30-60 rpm.

Nacelle — The nacelle sits atop the tower and encloses the gear box, low- and high-speed shafts, generator, controller, and brake. A cover protects the components inside the nacelle. Some nacelles are large enough for a technician to stand inside while working.



Parts of a wind turbine. Image courtesy DOE[30]

Power curve — Graph showing the power output of a wind turbine at various wind speeds.

Swept area — Space that turbine blades travel through. Larger swept areas capture more wind energy. Area Swept = $\pi * r^2$ (r = length of one blade)

Tower — Towers are made from tubular steel or steel lattice. Because wind speeds increase with height, taller towers enable turbines to capture more energy and generate more electricity than those with shorter towers.

Wind Power Classes at 10 m (33 ft) Elevation

Power Class	Wind Speed mph	Wind Speed m/s	Power Density W/m^2
1	0-9.8	0-4.4	0-100
2	9.8-11.5	4.4-5.1	100-150
3	11.5-12.5	5.1-5.6	150-200
4	12.5-13.4	5.6-6.0	200-250
5	13.4-14.3	6.0-6.4	250-300
6	14.3-15.7	6.4-7.0	300-400
7	15.7-21.1	7.0-9.4	400-1,000

Wind power class — NREL classification system of wind speeds and corresponding wind power.

Wind power density — Available power in the wind usually measured in watts per square meter.

Wind direction — The figure to the left illustrates an upwind turbine, so-called because it operates with the blades facing into the wind. Other turbines are designed to run downwind, with blades facing away from the wind.

Wind map — Map showing average annual wind speeds at a specified elevation.

Wind vane — Measures wind direction and communicates with the yaw drive to orient the turbine properly with respect to the wind. Also known as the tail.

Yaw drive — Upwind turbines require a yaw drive to keep the rotor facing into the wind.

*Terms and wind power chart courtesy DOE[31]

Wind Power

Does My Site Have Good Wind Energy Potential?

There is a space minimum as well as wind speed minimum for a wind power project to be feasible for your site. The potential site should be located on or near at least one acre of open, rural land. More importantly, it is necessary to have consistent wind speeds of at least 10 mph (4.5 m/s) at 33 ft (10 m) elevation. A common height for wind turbines is about 150 feet (45.7 m) where the wind speeds are about 25% greater than at 30 feet. In general, for a small wind turbine to be cost effective, it would need to be installed in an area that has at least Class 2 wind conditions.[32] Wind speeds at a site can vary based on topography and structural interference. Localized areas of good wind power potential such as a ridge-top may not show up on a wind map, so site-specific evaluations should be conducted to determine wind availability. Wind turbines should be sited in an area where obstructions or future obstructions, such as new buildings, will have minimal effect on the wind resource. Consult vendors to determine turbines models that will operate efficiently with wind speeds available at your site. To view average wind speed maps, visit:

www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp

Get site specific wind speed data using a recording anemometer, which generally costs from $500 to $1,500. The most accurate readings are taken at "hub height," the elevation at the top of the prospective wind turbine tower. This requires placing the anemometer high enough to avoid turbulence created by trees, buildings, and other obstructions.

Considerations

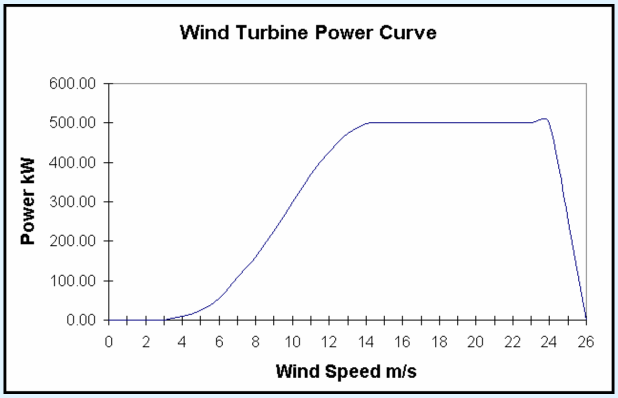
There has been concern over the aesthetic impact of wind turbines, the noise generated (especially by smaller turbines) and the impact on avian and bat wildlife that might fly into turbines. Careful siting of the turbines and continual technology improvements can mitigate these concerns. One should look into legal and environmental limitations for your city and county.

What Size Turbine is Right for My Site?

While solar panels are rated at an industry standard, there are no standards that apply to wind turbines. Each turbine is different so you must look at the specifications for each to estimate how much power it could generate given the wind availability at your site. The electricity produced by a wind turbine depends on the average wind speed at your site, length of blades, tower height, and efficiency of system components. Turbine models with high rated power at lower wind speeds will produce more energy because power in the wind is proportional to the cube of the wind speed. Wind turbine developers can help properly install a turbine that is well suited for conditions at your cleanup site. Though it is more expensive to install a taller tower, it is often a good investment because the return in energy production is greater. Installing a wind turbine is usually cost effective if electricity rates are more than 10 cents to 15 cents per kWh. Small turbines are considered to be 100 kW or less while large turbines are considered to be greater than 100 kW.

How to Read a Wind Turbine Power Curve

A wind turbine power curve shows the power output of a turbine at corresponding wind speeds. A wind turbine with the power curve shown below may be rated at 500 kW. What may not be stated upfront is that wind speeds of 14 m/s to 24 m/s are necessary to produce the rated power of 500 kW. Be sure to determine the power output of a turbine for wind speeds that are specific to your site.



Wind turbine power curve. Courtesy De Montfort Univerisity[33]

Wind Power

Cost

Smaller wind turbines cost between $2,000 and $7,000 per rated kW. A typical 10-kW wind turbine system will cost between $25,000 and $35,000. If placed in an area with wind speeds averaging 10-15 mph, it will produce between 10,000 and 18,000 kWh per year.[34] Used turbines will be much less expensive but should undergo remanufacturing by a qualified mechanic. Many parts should be replaced, even if they are still functioning since it is easier to replace parts while the system is already disassembled.[35]

Operation and Maintenance

Annual operating and maintenance costs are estimated to be about 1% of the capital costs. Alternator bearings need replacement after several years of operation. The same is true for yaw bearings given their significant loading. Check that bolts remain tight. Dust, debris, saltwater mist, and insects will eventually erode the most durable blade materials, leading edge tapes, and paint coatings. Paint coatings, subjected to sunlight, moisture, and temperature extremes will eventually deteriorate. Also, lubricant in the gearbox, like oil in a car engine, will degrade over time. Maintain the turbine as recommended by the manufacturer to ensure that it will continue to operate properly for many years.[36] A typical wind turbine lifetime is 20-30 years.

Permits

Permitting requirements, procedures, and fees for wind turbines vary by county. Costs for building permits, zoning permits, and use permits may range from $100 to $1,600. Wind turbine standards and regulations may include minimum land size, tower height restrictions, minimum distance from the edge of the property, and maximum noise levels. If your turbine tower is less than 20,000 feet from an airport runway or greater than 200 feet tall, you may need to get permission from the Federal Aviation Administration and/or add warning lights to your tower. The turbine must comply with the Uniform Building Code and National Electric Code. Consultants can help with permitting issues. Contact the local municipality for more information on permitting requirements.[37]

Funding Resources

Renewable Electricity Production Credit (REPC)

Commercial and industrial sectors are eligible. The tax credit is 1.9¢ per kWh of electricity produced by wind. The duration for the credit is for 10 years. A business can take the credit by completing IRS Form 8835 www.irs.gov/pub/irs-pdf/f8835.pdf and www.irs.gov/pub/irs-pdf/f3800.pdf. This incentive can be applied to wind turbines at PRP-lead facilities installed by December 31, 2008.

Renewable Energy Production Incentive (REPI)

This incentive is currently 1.9¢ per kWh produced for the first 10 fiscal years of the system's operation. Only generated energy that is sold to another entity can receive the production incentive. Check www.eere.energy.gov/repi for eligibility requirements.

Facilities must be in place by October 1, 2016.

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(303) 275-4755

Check for state and local incentives at **www.dsireusa.org**.

Wind Power Companies

There are many wind turbine manufacturers, retailers, designers, consultants, and installers. Check warranties, predicted lifetimes, and reputation of companies to make well informed decisions.

Directory of wind power companies:

- American Wind Energy Association: www.awea.org/faq/smsyslst.html
- Windustry: www.windustry.org/companies

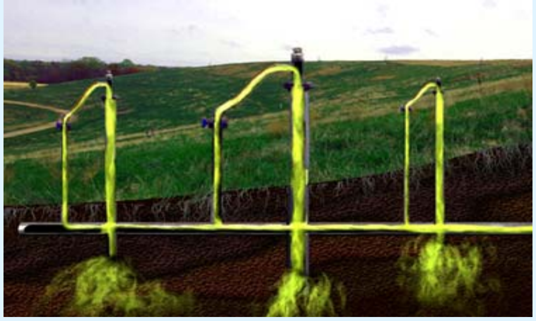
For More Information

- General information:
  American Wind Energy Association www.awea.org
- Technology information:
  U.S. Department of Energy www1.eere.energy.gov/windandhydro/wind_technologies.html
- Net metering information:
  U.S. Department of Energy www.eere.energy.gov/greenpower/markets/netmetering.shtml

Landfill Gas

Landfill Gas Basics

Municipal solid waste (MSW) landfills consist of everyday garbage generated from residences, businesses, and institutions.[38] Superfund landfills are usually co-disposal facilities that include hazardous waste as well as MSW. The decomposition of MSW creates **landfill gas (LFG)**. This gas is composed of about 50% carbon dioxide (CO_2), 50% methane (CH_4), and traces of **non-methane organic compounds (NMOC)**. Co-disposal landfills tend to produce higher concentrations of NMOC and air toxics. Methane, the major component of natural gas, is a high energy gas that is used to provide energy for homes, businesses and industries. Instead of wasting a valuable energy source by flaring the LFG, it can be collected from landfills and used directly for heating and/or to generate electricity by implementing a **Landfill-Gas-to-Energy (LFGE)** project. A series of wells drilled into the landfill can collect the gas and transport it through a system of pipes to be cleaned and then used to power engines or turbines to produce electricity for use on your Superfund site. Co-disposal landfills usually produce less methane due to the age of the landfill and amount of inert materials buried, rather than decomposable MSW waste. Use EPA's *Guidance for Evaluating Landfill Gas Emissions From Closed or Abandoned Facilities* (www.epa.gov/nrmrl/pubs/600r05123/600r05123.pdf) to evaluate potential emissions from Superfund landfills.



Landfill gas wells and piping.
Image courtesy LMOP[39]

Landfill gas treatment/blower/flare station.
Image courtesy LMOP[40]

What is the Potential Energy Production from a Landfill?

As a basic rule of thumb, 432,000 ft^3 of LFG is produced per day for every million tons of MSW in a landfill. This is equivalent to 0.8 megawatts (MW) of power that could be generated. Site measurements are recommended, especially for co-disposal landfills, to more accurately quantify LFG flow rates. When LFG is uncontrolled, it is released into the atmosphere, contributing to smog and climate change. Utilizing LFG as an energy source reduces direct emissions from the landfill, as well as offsets emissions otherwise emitted from fossil fuel use, such as particulate matter (PM), sulfur dioxide (SO_2), and carbon dioxide (CO_2).[41] There are many factors that effect the amount of gas produced for each landfill. Some of the most important factors are:

- **Depth of landfill** — A landfill with a depth of at least 40 feet would be an ideal candidate because this depth suits anaerobic conditions for producing LFG. However, LFGE project have been successfully implemented in shallower landfills.
- **Amount of waste** — A landfill with at least one million tons of MSW is optimal. Smaller landfills are good candidates if the gas will be used on-site or close by.
- **Type of waste** — Decomposing organic wastes like paper and food scraps produce the most landfill gas. Landfills with a lot of construction and demolition, industrial, or hazardous wastes may not be as productive.
- **Age of landfill** — As a landfill ages, the rate of methane production decreases. Landfills that are still open or have recently closed have the best potential for a LFGE project.
- **Rainfall** — The bacteria that break down the waste thrive best in moisture. An optimal site will have at least 25 inches of rainfall a year. Landfills in arid climates may produce gas at a lower rate but are expected to produce gas for a longer period of time.[42]

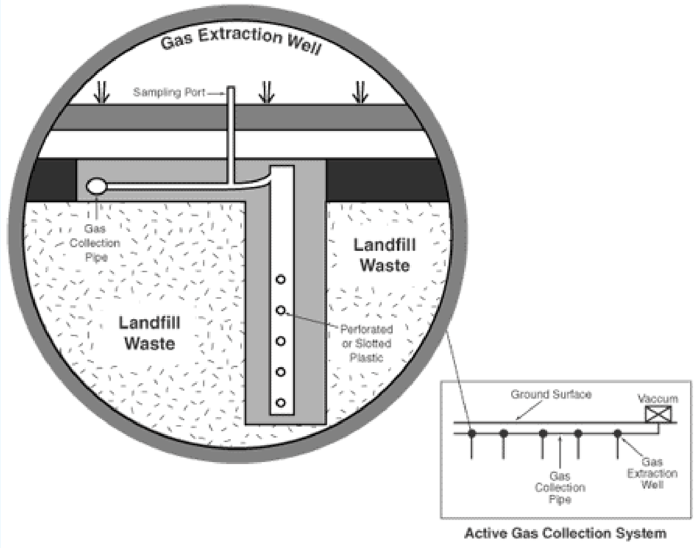
LANDFILL GAS SAFETY

LFG is potentially explosive, may pose an asphyxiation hazard, and may cause headaches and nausea due to odors. LFG collection systems minimize exposure. Always take precautions when handling LFG. For more information, see: www.atsdr.cdc.gov/HAC/landfill/html/toc.html

Landfill Gas

How is Landfill Gas Used?

Landfill gas is approximately 50% carbon dioxide and 50% methane. The methane can be (a) used directly as a boiler fuel to produce hot water or steam to run a steam turbine or for other processes; (b) used as a fuel to power internal combustion engines or turbines to generate electricity; or (c) treated to become pipeline-quality gas.



Gas extraction schematic. Image courtesy LMOP[43]

LFGE Systems

Collecting landfill gas for energy production requires three components:

1. Gas Collection and Backup Flare:

Gas collection typically begins after a portion of a landfill (called a cell) is closed. A collection well is drilled into the landfill to collect the LFG. Each LFG wellhead is connected to lateral piping, which transports the gas to a main collection header. An aqueous condensate forms when warm gas from the landfill cools as it travels through the collection system. If condensate is not removed, it can block the collection system and disrupt the energy recovery process. Sloping pipes and headers in the field collection system are used to drain condensate into collecting ("knockout") tanks or traps. Condensate could be recirculated to the landfill, discharged to the public sewer system, or treated on-site. Most landfills with energy recovery systems have flares for combusting excess gas and for use during equipment downtimes.

2. Gas Treatment:

The collected LFG must be treated to remove any condensate that is not captured in the knockout tanks. NMOC and air toxics must be properly treated. Removal of particles and other impurities depend on the end-use application of the LFG. For example, minimal treatment is required for direct use of gas in boilers, while extensive treatment is necessary to remove CO_2 and other trace organic compounds for injection into a natural gas pipeline. Power production applications typically include a series of filters to remove impurities that could damage engine components and reduce system efficiency.

3. Energy Recovery:

Internal combustion (IC) engines, **combustion turbines (CTs)**, and **boiler/steam turbines** can produce electricity using lFG. The IC engine is the most commonly used conversion technology in LFG applications. IC engine projects typically have higher rates of NO_x emissions than other technologies which may cause permitting issues. Usually, NO_x controls can be installed to meet local requirements. CTs are typically used in medium to large LFGE projects, where landfill gas volumes are sufficient to generate a minimum of 3-4 MW. One of the primary disadvantages of CTs is that they require high gas compression levels. More energy is required to run the compression system for CT systems, as compared to other options. However, CTs are much more resistant to corrosion damage than IC engines and have lower NO_x emission rates. They are also relatively compact and have low operations and maintenance costs in comparison to IC engines. The boiler/steam turbine configuration is the least used of these three landfill gas power conversion technologies. It is applicable mainly in very large landfill gas projects, where gas flows support systems of at least 8-9 MW. The boiler/steam turbine consists of a conventional gas or liquid fuel boiler, and a steam turbine generator to produce electricity. This technology usually requires a complete water treatment and cooling cycle, plus an ample source of process and cooling water.[44] Lastly, note that LFG may be corrosive to LFG collection and electricity generation parts and equipment so proper maintenance is necessary to keep the system running safely and efficiently.

Landfill Gas

Landfill Gas Terms

Boiler / Steam turbine — A boiler produces thermal energy from burning methane gas. This heat is used in a steam turbine to generate electricity. This configuration is best suited for landfills with gas production of greater than 5 million cubic feet per day. It is the least used among landfill gas projects because it is more expensive than other gas power conversion technologies for the typical size of LFGE projects.

Collection wells — Wells are strategically dug into a landfill to collect LFG. The gas collection system transports the gas to be treated and used to generate electricity or as a fuel for heating applications.

Combustion (Gas) turbine — Combustion turbines (CTs) are typically used in medium to large landfill gas projects, where landfill gas production is approximately 2 million cubic feet per day. This technology is competitive in larger landfill gas electric generation projects because of significant economies of scale. The efficiency of electricity generation generally improves as size increases.

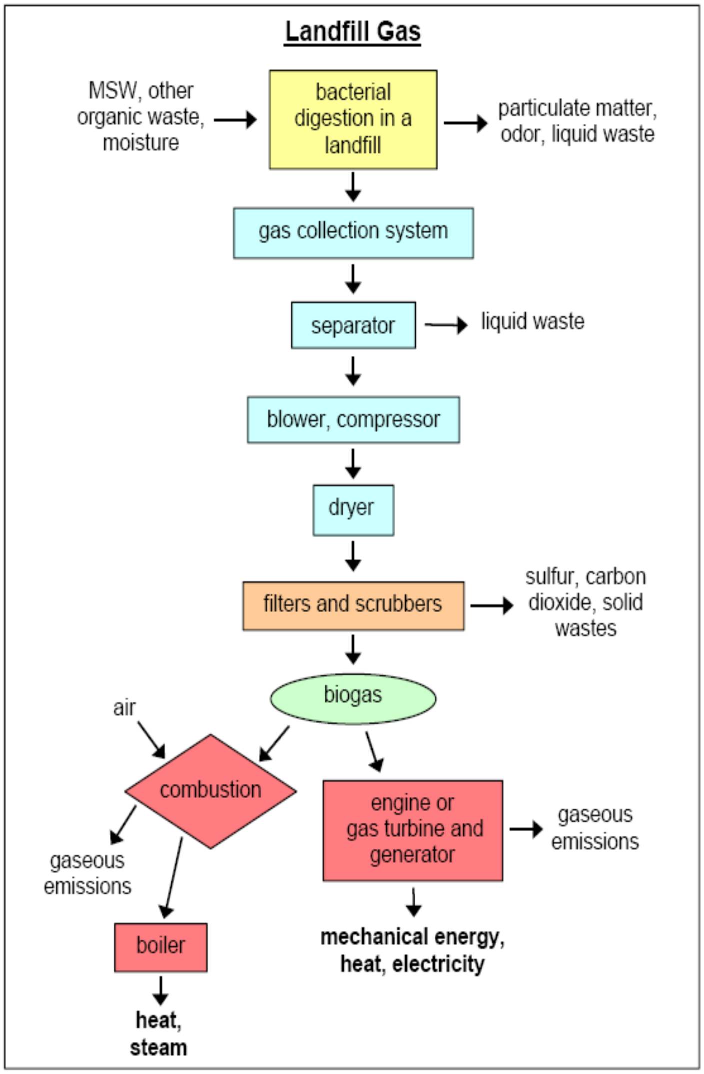
Compressor — This device changes the density of the landfill gas to be compatible for use in an internal combustion engine, combustion turbine, or microturbine.

Condensate — Condensate is a liquid that forms from water and/or other vapors in the landfill gas that condense as LFG travels through the pipes. Proper disposal of condensate is necessary.

Internal combustion engine / reciprocating engine — This engine is the most widely used electricity generation technology for LFG. They are typically used for generation projects greater than 800 kW.

Methane (CH_4) — Methane is a highly combustible greenhouse gas that makes up about 50% of gas emitted from an MSW landfill. This gas can be used directly to generate heat or as a fuel to produce electricity. Methane makes up more than 90% of typical natural gas.

Microturbine — Each unit produces 30-250 kW and can be combined with each other. They are better suited to landfills where gas production is too low (low concentrations of methane and/or low flow) to economically use a larger engine, for landfills with onsite energy use, or for use in areas where the use of larger technologies is not feasible. The total installed cost for a LFG microturbine project is estimated to be $4,000 to $5,000 per kW for smaller systems (30 kW).[45]



Landfill gas to energy processes. Image courtesy Oregon Department of Energy[46]

Possible Business Models

The following are possible business models that outline LFGE operations and maintenance roles:

1) Landfill owner owns and manages all LFGE equipment and sells electricity to the utility or directly to an end user.
2) Landfill owner owns LFG collection system. Electricity generation equipment owned and operated by utility; the utility purchases landfill gas from landfill owner.
3) Landfill owner provides LFG. Third party owns and operates LFG collection system and electricity generation equipment.

Landfill Gas

Permitting Issues

LFGE recovery projects must comply with federal regulations related to both the control of LFG emissions and the control of air emissions from the energy conversion equipment. Emissions need to follow Clean Air Act and Resource Conservation and Recovery Act regulations. States may have more stringent requirements. Permits can take more than a year to attain. No construction should begin until permitting issues are resolved since permits may affect the design of the project. Permits in the following areas may be required:

- **Air Quality**
- **Building Permit**
- **Land use Permit**
- **Noise**
- **Wastewater**
- **Condensate**
- **Water**
- **Stack height**

Costs and Benefits of a LFGE Project

Cost of a landfill gas project varies depending on a variety of factors including the size of landfill, type of electricity generation technology, and site specific characteristics. A one million ton MSW landfill in 2002 with a typical landfill gas collection and control system cost around $600,000-$750,000 and O&M cost for this size landfill is approximately $40,000-$50,000 a year.[47] Site preparation and installation costs vary significantly among locations but electricity generation equipment account for about 30-70% of the capital cost. Total capital cost includes the engine/turbine, auxiliary equipment, interconnections, gas compressor, construction, and engineering services. Some landfills may already have a gas collection system in place.[48] Use the following resources to estimate LFGE costs and benefits for an MSW landfill gas project.

Landfill Gas Emissions Model (LandGEM) This model can be used to estimate total LFG, methane, carbon dioxide, non-methane organic compounds, and other emissions from MSW landfills.
www.epa.gov/ttncatc1/products.html#software

Landfill Gas Energy Cost Model Use this tool to estimate the economic feasibility of an MSW LFGE project.
www.epa.gov/lmop/res#5

LFGE Benefits Calculator Use this tool to estimate greenhouse gas reductions from a LFGE project.
www.epa.gov/lmop/res#5

Landfill Methane Outreach Program

The Landfill Methane Outreach Program (LMOP) is an EPA assistance and partnership program that promotes the use of landfill gas as a renewable, green energy source. LMOP partners and forms agreements with communities, landfill owners, utilities, power marketers, states, the LFG industry, tribes, non-profit organizations, and trade associations to overcome barriers to project development by helping them assess project feasibility, financing, and marketing the benefits of project development to the community. LMOP provides technical, informational, and marketing services, such as:

- Technical assistance, guidance materials, and software to assess a potential project's economic feasibility;
- Assistance in creating partnerships and locating financing for projects;
- Informational materials to help educate the community and the local media about the benefits of LFG; and
- Networking opportunities with peers and LFG experts to allow communities to share challenges and successes.

Contact LMOP for assistance on your landfill project:
www.epa.gov/lmop/contact

Funding Resources

Renewable Electricity Production Credit (REPC)
Corporate tax credit of 1.9¢ per kWh produced for a period of 10 years. Project must be operational by Jan 1, 2009. To apply for the credit, a business must complete www.irs.gov/pub/irs-pdf/f8835.pdf and www.irs.gov/pub/irs-pdf/f3800.pdf

Renewable Energy Production Incentive (REPI)
Credit of 1.0¢ per kWh generated and sold for a period of 10 years, until 2026, if funds are available. Contact: christine.carter@go.doe.gov or repi@ee.doe.gov Check www.eere.energy.gov/repi.html for eligibility requirements.

Check the following websites for more opportunities:

www.epa.gov/lmop/res/guide

www.dsireusa.org

For Net Metering Information:
www.eere.energy.gov/greenpower/markets/netmetering.shtml

Anaerobic Digester

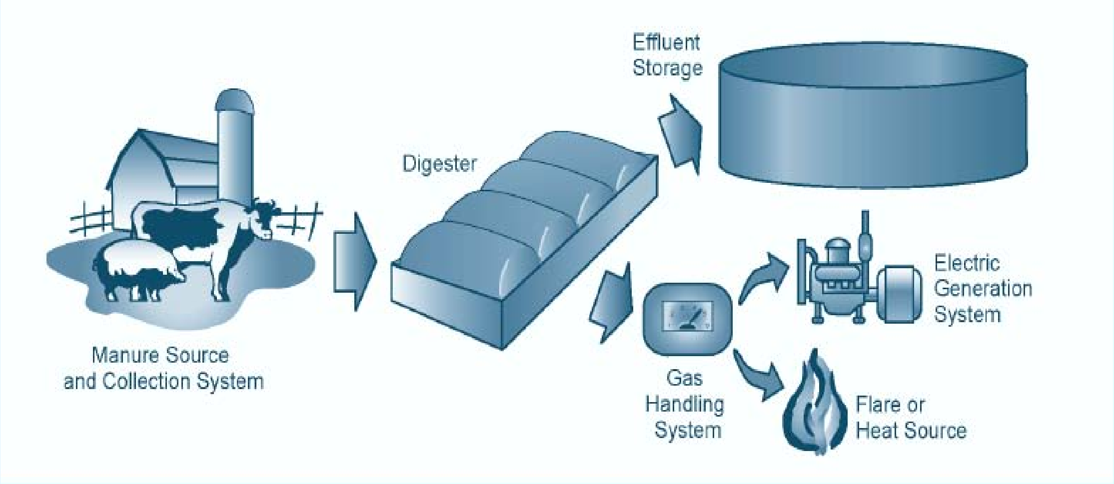
Anaerobic Digester Basics

Anaerobic digestion is the natural process of decomposing organic materials such as manure, wastewater treatment facility residuals, agricultural wastes and food processing wastes, by bacteria in an oxygen-free environment. One of the products of anaerobic digestion is biogas, which consists of 60-70% methane, 30-40% carbon dioxide, and trace amounts of other gases. This natural process can be manipulated in a controlled environment, such as in an anaerobic digester, where the methane gas can be collected and used for heating and/or electricity production.[49] Digesters may be designed as plastic or rubber covered lagoons, troughs, or as steel or concrete tanks. Carefully controlled nutrient feed, moisture, temperature, and pH in the digester can make a habitable environment for anaerobic bacteria, which are naturally occurring in manure. Digesters work best with biomass that is greater than 85% moisture by weight. Digesters can operate at two ideal temperature ranges: mesophilic (95˚F-105˚F) which best host mesophile bacteria, and thermophilic (125˚F-135˚F), which best host thermophile bacteria. Waste heat from electricity generators can be used to heat the digesters. Thermophilic conditions decrease the hydraulic retention time (time the organic matter remains in digester), thus reducing the size of the digester needed. However, thermophilic bacteria are also much more sensitive to changes in their environment so digester conditions must be closely monitored and maintained. There is little change in the volume of the feedstock after it goes through the digester. The digested material can be used as high-quality fertilizer. The effluent can be spread on fields as a liquid fertilizer or liquids and solids can be separated to be sold individually. Some liquid content can be re-fed into the digester in the case that moisture content of the feedstock needs to be increased.

The Digester System

The digester system components include:

- **Nutrient source** — Organic material Including animal manure, wastewater treatment sewage sludge, food processing waste, or agricultural waste. It is possible to combine different sources of organic matter to feed into a digester.
- **Transport system** — Most digesters are constructed onsite near the nutrient source. The organic matter must be collected and fed into the digester.
- **Pre-treatment tank** — Sometimes a pre-treatment tank is recommended in order to settle out sand, grit, and other contaminants from the organic feedstock before transporting into the digester.
- **Digester** — Choose a digester that suits your site-specific characteristics (see page 16).
- **Gas handling system** — Biogas is collected and processed to remove moisture and contaminants to the degree necessary for end use.
- **Electricity generation system** — Reciprocating engines, gas turbines, boilers / steam engines, or microturbines and generators can produce electricity using methane gas.
- **Flare or heat source** — Excess methane is flared. Methane can also be used directly for heating the digester or other processes.
- **Effluent storage** — Digested manure is stored for later use. It can be spread on fields as a liquid fertilizer. Solids can also be separated for use as a solid fertilizer.



Schematic of digester system. Image courtesy AgStar [50]

Anaerobic Digester

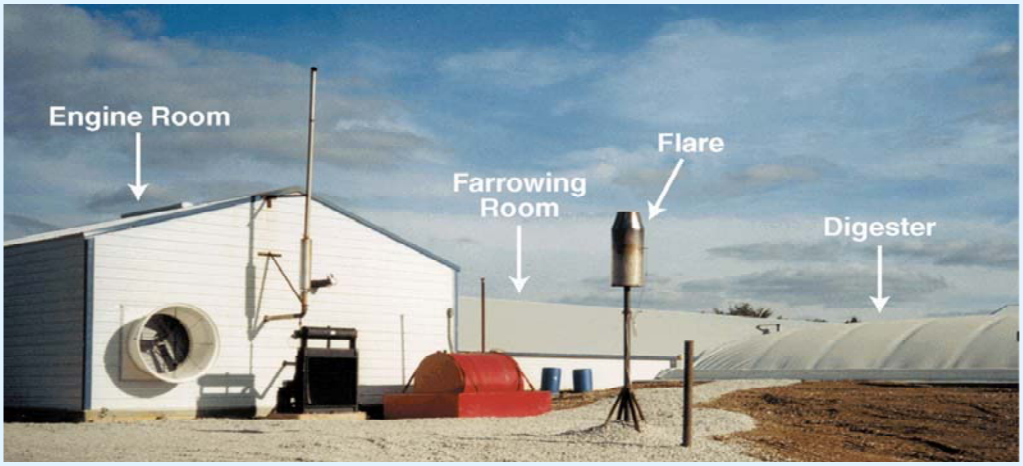
Conventional Types of Anaerobic Digesters

There are many types of anaerobic digesters. A digester suitable for your site depends on the moisture content of the influent and, in the case of covered lagoon digesters, climate at the site.

Fixed-film digester. Image courtesy University of Florida[52]

- Complete-mix digester — The complete-mix digester is a vertical concrete or steel circular container that can be installed above or below ground. It can handle organic wastes with total solid concentration of 3-10%, such as manure or food waste collected from a flush system. Complete-mix digesters can be operated at either the mesophilic or thermophilic temperature range with a hydraulic retention time (HRT) of 10-20 days. A mixer keeps the solids in suspension. This type of digester is usually more expensive to build and maintain than the plug-flow or lagoon digesters.
- Plug-flow digester — The basic plug-flow digester design is a rectangular trough, often built below ground level, with an impermeable, flexible cover. Organic waste is added to one end of the trough and decomposes as it moves through the digester. Each day a new "plug" of organic wastes is added, pushing the feedstock down the trough. Plug-flow digesters are suitable for organic wastes with total solid concentration of 11-13%, with a HRT of 20-30 days. Suspended heating pipes of hot water stir the slurry through convection. This type of digester has few moving parts and requires little maintenance.
- Covered lagoon digesters — A covered lagoon is an earthen lagoon fitted with a floating, impermeable cover that collects biogas as it is produced from the organic feedstock. A lagoon is best suited for liquid organic wastes with a total solid concentration of 0.5-3%. Covered lagoon digesters are generally not heated so they must be located in warmer climates for them to produce enough biogas for energy production. This type is the least expensive of the three. See page 19 for more on digester costs.
- Other Digester Designs[51]
  - Advanced integrated pond system
  - Up-flow solids reactor
  - Fixed film
  - Temperature-phased
  - Anaerobic filter reactor

Plug flow digester. Image courtesy Penn State University[53]



Typical digester configuration Image courtesy U.S. EPA[54]

Anaerobic Digester

Digester Terminology

Anaerobic — Absence of oxygen.

Anaerobic Digester — Sealed container in which anaerobic bacteria break down organic matter and create biogas.

Biogas — Gas produced from decomposition of organic matter in an anaerobic digester. Consists of 60-80% methane, 30-40% carbon dioxide, and other trace gases such as hydrogen sulfide, ammonia and hydrogen.

Effluent — Organic liquid and solid material leaving a digester.

Feedstock — Liquid and solid material fed to the digester, usually manure, also known as influent.

Hydraulic Residence Time (HRT) — The average length of time the influent remains in the digester for decomposition.

Influent — Liquid and solid material fed to the digester.

Methane — A combustible gas produced by anaerobic digestion, also the principle component of natural gas.

Mesophilic — Temperature range between 95°F and 105°F in which methanogenic microbes thrive.

Thermophilic — Temperature range between 125°F and 135°F where certain methanogenic bacteria are most active. The greatest pathogen destruction occurs in this temperature range.

Slurry – The mixture of biomass processed in the digester.

Terminology courtesy of Penn State University[55]

Energy Production

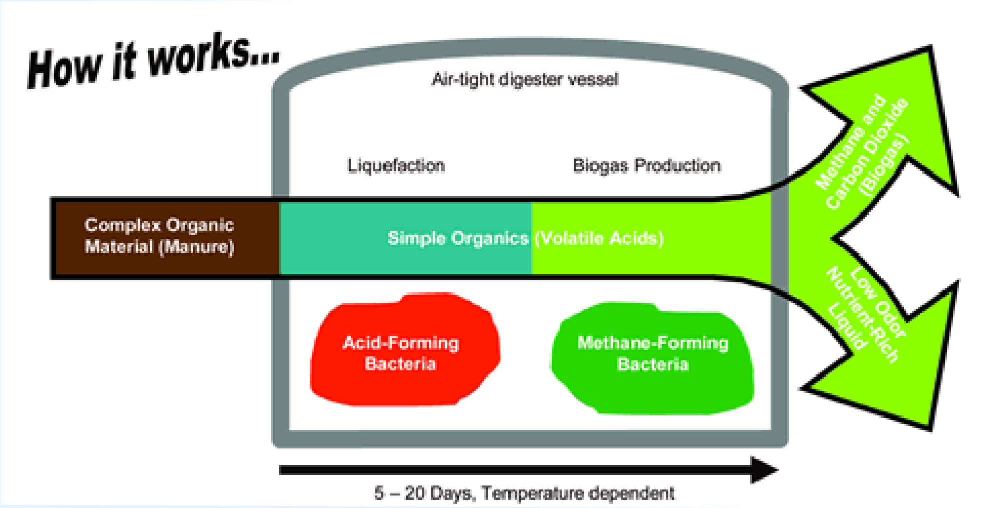
Producing biogas is the first step to harnessing energy from organic wastes. Then, engines or boilers coupled with generators convert the energy in the biogas into heat and/or electricity to be used on the cleanup site.

Internal Combustion Engine / Reciprocating Engine: An internal combustion engine is the most commonly used technology for utilizing biogas. The biogas must have condensate and particulates removed.

Boiler / Steam Turbine: The boiler produces thermal energy from burning the methane gas. This heat is used in a steam turbine to generate electricity. This configuration is best suited for digesters that produce more than 5 million cubic feet of methane per day.

Combustion (Gas) Turbine: Combustion turbines (CTs) are typically used in medium to large biogas projects. This technology is competitive in larger biogas electric generation projects because of significant economies of scale. The biogas must have most of the visible moisture and particulates removed and then compressed in order to be utilized in a gas turbine combustion chamber.

Microturbine: Microtrubines range in size from 30kW - 250kW and can be combined. They are better suited for digester projects for which gas production is too low (low concentrations of methane and/or low flow) to economically use a larger engine and for projects with onsite energy demand. A microturbine costs from $700 per kW to $1,100 per kW. The addition of a heat recovery system, which captures the otherwise wasted heat, adds between $75 and $350 per kW.[56] Microturbines require very clean biogas fuel, increasing the cost for biogas cleanup.



Anaerobic Digestion process. Image courtesy Penn State University[57]

Anaerobic Digester

Assessing Anaerobic Digester Potential

To consider an anaerobic digester energy project, a Superfund site should be close to an organic waste source. It may also be possible to collect organic wastes from a community, such as local farms and food processing facilities, though transportation costs must be taken into consideration. As a general rule of thumb for a manure biomass energy project, facilities should have at least 300 head of dairy cows or steers, 2,000 swine in confinement, or 50,000 caged layers or broilers (types of fowl) where manure is collected regularly.[58] This influent source should be available year round for a constant supply of biogas for energy production. Also, anaerobic digesters need material with high moisture content. The influent should be collected as a liquid, slurry, or semi-solid from a single point daily or every other day. Alternatively, water may be added after collection. Consider gasification technologies for drier materials. Digesters work best with manure that have as little bedding materials as possible. It may be necessary to have at least one person who can manage the digester for daily and annual maintenance. Consider uses for the digested material, both liquid and solid components, such as fertilizers.

Benefits of Anaerobic Digesters

- Green energy production
- Reduced odor compared to stored liquid manure, reducing potential nuisance complaints
- Digested effluent can be pumped long distances
- Reduction in pathogens and weed seeds in digested manure
- Fly propagation reduced
- Solids separation of digested manure—solids can be used as bedding or fertilizer. The fiber in digested dairy manure can be used on farms as bedding or recovered for sale as a high-quality potting soil ingredient or mulch. Digested liquids can be used as liquid fertilizer. Because anaerobic digestion reduces ammonia losses, digested manure can contain more valuable nitrogen for crop production. Nutrient content of digested manure is equal to that of the raw manure.

Maintenance and Operations

Anaerobic digesters require daily maintenance checks and longer term maintenance. Daily maintenance includes checking proper digester and engine function (e.g., gas leaks in digester cover or piping, oil level in the engine, film buildup in the digester). Daily maintenance takes from 10 minutes to 1 hour a day. Oil in the engine may need changing every few months. Digesters may need to be cleaned out after several years of operation. Biogas is a potentially dangerous gas. Take precautions including, but not limited to, installing gas detectors and posting warning signs and never entering an empty digester without extensive venting. Developers should train the owner to properly maintain and operate the system to ensure efficiency and safety. Go to http://www.biogas.psu.edu/Safety.html for more information on digester safety.

How Much Energy Can be Produced?

The amount of energy produced by an anaerobic digester system depends upon the type of organic matter, digester type, environment inside the digester, loading rate, and type of energy recovery technology. The following biogas production rates are based on laboratory tests and excludes these efficiency factors.

Animal (pounds of live animal)	Biogas Production per day (ft^3)	BTU* production per hour
Beef (1,000 lbs)	31	775
Dairy (1,200 lbs)	22.7	568
Poultry (4 lbs)	0.21	5.25
Swine (150 lbs)	4.1	103

(Chart courtesy of University of Missouri)[59] *3,414 BTU = 1 kWh

Relationships Among Involved Parties

Consider the following:

- Appropriate level of involvement with local utility if the digester is to produce a large excess amount of energy that can be net metered or sold to the utility.
- The need for a formal agreement with agricultural operator / food processor.
- Which party will own, operate, and manage the digester.

Anaerobic Digester

Permits

It is essential to garner appropriate permits early in the digester planning process as the design may need adjustment to comply with federal, state, and local rules. Anaerobic digester construction and operation may need permits in the following areas:

- Land use
- Confined Animal Facility Operation Permit
- Noise
- Wastewater
- Water
- Stormwater management
- Air

Emissions Issues

NO_x emissions from combusting biogas may be of concern for a digester project. Naturally aspirated reciprocating internal combustion engines emit relatively high levels of NO_x. Fuel injected lean-burn reciprocating internal combustion engines provide greater engine power output and lower NO_x emissions compared to a naturally aspirated engine. Gas turbines emit even lower levels of NO_x. SO_x may be produced from swine manure digesters and may necessitate the use of scrubbers. SO_x emissions are generally not a concern for other types of influent.

Cost

For a manure digester, EPA AgStar estimates that a covered lagoon and heated digester will cost about $200-$450 per 1,000 pounds of live animal weight that contribute to the influent and a 3-7 year payback period. Download FarmWare from www.epa.gov/agstar/resources.html to get a preliminary feasibility and economic analysis for swine or dairy manure feedstock.

Possible Business Models

The following are possible business models that outline digester operations and maintenance roles:

- Producer of organic matter owns and manages digester and electricity generation equipment.
- Producer of organic matter owns and manages digester. Electricity generation equipment owned and operated by utility; the utility purchases the biogas from digester owner.
- Producer of organic matter provides influent. Third party owns and operates digester and electricity generation equipment.

Funding Resources

USDA Conservation Innovation Grants

These are competitive federal grants that target innovative conservation approaches and technologies. Grant monies and topics range year to year. For fiscal year 2008, the grant can provide up to 50% of project costs, not to exceed $1 million. Apply for state grants for smaller projects.
www.nrcs.usda.gov/programs/cig/
www.nrcs.usda.gov/programs/cig/statecomponent.html
Contact: Tessa Chadwick (202) 720-2335
tessa.chadwick@wdc.usda.gov

Farm Pilot Project Coordination, Inc. (FPPC)

FPPC is a not-for-profit organization designated by Congress that assists in implementing innovative treatment technologies to address animal waste issues from animal feeding operations. About $2-$3 million is available per RFP round and each project is eligible for up to $500,000.
www.fppcinc.org info@fppcinc.org (800) 829-8212

Renewable Energy and Energy Efficiency Program
Department of Agriculture: Rural Development

This program provides competitive grants and guaranteed loans for rural agriculture producers and small businesses to purchase renewable energy systems and make energy efficiency improvements.
www.rurdev.usda.gov/rbs/

Renewable Electricity Production Credit (REPC)

Corporate Tax Credit of 1.0¢ per kWh produced for a period of 10 years. Project must be operational by Jan 1, 2009. To apply for the credit, a business must complete www.irs.gov/pub/irs-pdf/f8835.pdf and www.irs.gov/pub/irs-pdf/f3800.pdf

Renewable Energy Production Incentive (REPI)

Credit of 1.9¢ per kWh generated and sold for a period of 10 years, until 2026, if funds are available. Go to www.eere.energy.gov/repi.html for more information.

For More Information

EPA AgStar

AgStar is an EPA program that specializes in agricultural waste issues. Use the AgStar Handbook to appraise the feasibility outlook of powering your site with a digester. These resources are especially helpful for swine or dairy manure. www.epa.gov/agstar

Penn State University
www.biogas.psu.edu/anaerobicdigestion.html

Cornell University
www.manuremanagement.cornell.edu

Agricultural Biogas Casebook Update 2004
www.rs-inc.com/downloads/Experiences_with_Agricultural_Biogas_Systems-2004_Update.pdf

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