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Smart Energy Resources Guide

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Smart Energy Resources Guide

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Foreword

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Sally Gutierrez, Director
National Risk Management Research Laboratory

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All links in this document are active as of February 26, 2008.

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About the Regional Applied Research Effort

The Regional Applied Research Effort (RARE) Program promotes collaboration between the EPA regional offices and the EPA Office of Research and Development (ORD). The goals of the program are to:

- Provide the regions with near-term research on high-priority, region-specific science needs,
- Improve collaboration between regions and ORD laboratories and centers, and
- Build a foundation for future scientific interaction.

ORD provides $200,000 per year to each region to develop a research topic or topics, which are then submitted to a specific ORD laboratory or center as an extramural research proposal. Once approved, the research is conducted as a joint effort with ORD researchers and regional staff working together to meet region-specific needs. Each region's Regional Science Liaison (RSL) coordinates RARE Program activities and is responsible for ensuring the research results are effectively communicated and utilized in the region.

Past RARE research topics have touched upon all aspects of environmental sciences, from human health concerns to ecological effects of various pollutants. However, the RARE Program can be used as a tool to address any type of issue or problem that a region identifies as a high priority research need and for which ORD has the necessary expertise and capability to address.

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Acronyms and Abbreviations

AC	Alternating current
AFO	Animal feeding operations
AFV	Alternative fuel vehicles
AH	Amp-hours
ASTM	American Society for Testing and Materials
AWEA	American Wind Energy Association
BACT	Best available control technologies
bhp-hr	Brake horsepower - hour
BIPV	Building-integrated photovoltaic
BTU	British thermal unit
C	Carbon
CARB	California Air Resources Board
CCA	Cleanup-Clean Air Initiative
CEC	California Energy Commission
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cf	Cubic foot
cfd	Cubic foot per day
CFDA	Catalog of Federal Domestic Assistance
cfm	Cubic foot per minute
CFR	Code of Federal Regulations
CH_4	Methane
CHP	Combined heat and power
CIG	Conservation Innovation Grants
CMAQ	Congestion Mitigation and Air Quality
CMP	Carl Moyer Memorial Air Quality Standards Attainment Program
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
CPUC	California Public Utilities Commission
CREBs	Clean Renewable Energy Bonds
CSI	California Solar Initiative
CSP	Concentrated solar power
CT	Combustion turbine
DC	Direct current
DCA	Dichloroethane
DOC	Diesel oxidation catalyst
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DPF	Diesel particulate filter
EERE	DOE Office of Energy Efficiency and Renewable Energy

EGR	Exhaust gas recirculation
EIA	DOE Energy Information Administration
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPAct	Energy Policy Act
EPBB	Expected performance base buydown
EQIP	Environmental Quality Incentives Program
ERP	Emerging Renewables Program
ERRS	Emergency and Rapid Response Service
FEMP	Federal Energy Management Program
FPPC	Farm Pilot Project Coordination, Inc.
FY	Fiscal year
GAC	Granulated activated carbon
GCW	Groundwater circulation wells
GHG	Greenhouse gas
GRO	Greater Research Opportunities
GSA	General Services Administration
GSFC	Goddard Space Flight Center
GW	Gigawatt
H_2	Hydrogen
HC	Hydrocarbons
hp	Horsepower
HRT	Hydraulic retention time
IC	Internal combustion
IEA	International Energy Agency
IRS	Internal Revenue Service
kg	Kilogram
kW	Kilowatt
kWh	Kilowatt-hour
kWh/m^2	Kilowatt-hour per square meter
lfg	Landfill gas
LFGE	Landfill gas-to-energy
LMOP	Landfill Methane Outreach Program
LNG	Liquefied natural gas
lsd	Low-sulfur diesel
µm	Micrometer
m	Meter
m^2	Square meter
m/s	Meters per second
MACRS	Modified Accelerated Cost-Recovery System
MSW	Municipal solid waste
mph	Miles-per-hour
MOA	Memorandum of agreement

MPO	Metropolitan planning organization
MW	Megawatt
NASA	National Aeronautics and Space Administration
NCDC	National Clean Diesel Campaign
NEG	Net excess generation
NETL	DOE National Energy Technology Laboratory
NMOC	Non-methane organic compounds
NNEMS	National Network for Environmental Management Studies
NO_x	Nitrogen oxides
NREL	DOE National Renewable Energy Laboratory
O&M	Operations and maintenance
OII	Operating Industries Incorporated
ORD	EPA Office of Research and Development
OTAQ	U.S. EPA Office of Transportation and Air Quality
P2	Pollution Prevention
P&T	Pump-and-treat
PBI	Performance based incentive
PCE	Perchloroethylene
PG&E	Pacific Gas and Electric Company
pH	Potential of hydrogen
PIER	Public Interest Energy Research
PM	Particulate matter
PPA	Power purchase agreement
ppm	Parts per million
PRP	Potentially responsible party
psig	Pounds-force per square inch gauge
PV	Photovoltaic
RAC	Response Action Contracts
RARE	Regional Applied Research Effort
RCRA	Resource Conservation and Recovery Act
RD&D	Research, development and demonstration
RD/RA	Remedial Design/Remedial Action
REC	Renewable energy credit/certificate
REPC	Renewable Electricity Production Tax Credit
REPI	Renewable Energy Production Incentive
RFP	Request for proposals
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPM	Remedial project manager
RPM	Revolutions per minute
RSL	Regional science liaison
SARE	Sustainable Agriculture Research and Education
SCE	Southern California Electric Company

scfm	Standard cubic feet per minute
SDG&E	San Diego Gas and Electric Company
SERG	Smart Energy Resources Guide
SGIP	Self Generation Incentive Program
SOW	Statement of work
SO_2	Sulfur dioxide
SO_x	Sulfur oxides
SVE	Soil vapor extraction
TCA	Trichloroethane
TCE	Trichloroethylene
TOU	Time-of-use
ulsd	Ultra-low-sulfur diesel
USDA	U.S. Department of Agriculture
VOCs	Volatile organic carbons
W	Watt
W/m^2	Watts per square meter
WRAP	Western Regional Air Partnership
WURD	Western United Resource Development Corporation

EXECUTIVE SUMMARY

Remedial actions taken to clean up hazardous waste sites for environmental restoration and potential reuse are often sources of diesel and greenhouse gas (GHG) emissions. Many remediation systems, such as pump-and-treat (P&T), may operate for many years, demanding electricity from fossil-fuel powered utilities. Heavy-duty equipment used in construction during site remediation are usually diesel powered. Opportunities to lessen these emissions exist through innovative approaches and new technologies. The purpose of this guide is to provide information on available mechanisms to reduce these emissions at cleanup sites.

Reducing GHG and diesel emissions are important challenges facing this country. Executive orders have been issued and federal and state laws passed to address both concerns. GHG emissions from human activities are directly linked to global climate change. Diesel emissions are known to cause premature deaths and a wide variety of respiratory illnesses. The Cleanup-Clean Air Initiative (CCA) was established by the U.S. Environmental Protection Agency (EPA) Region 9 Superfund and Air Divisions to encourage GHG and diesel emissions reductions at cleanup sites. Through these efforts, CCA staff have engaged in pilot projects and changed Emergency and Rapid Response Service and Response Action Contracts to include language on renewable energy and clean diesel.

This document discusses many opportunities to reduce emissions due to energy use from remediation activities. Examples include energy efficiency upgrades, implementing on-site renewable energy projects, and carbon sequestration. An overview of renewable energy technologies is presented including costs, availability, applicability, estimated emissions reduction benefits, considerations, permitting, vendor information, funding resources and success stories. Renewable energy technologies covered in this guide are solar, wind, landfill gas, anaerobic digesters, and gasifiers. Additional methods for utilizing renewable energy are provided. Similar information is provided for diesel emissions reduction technologies and cleaner fuels. This document includes information on reducing diesel emissions through retrofitting diesel equipment, using cleaner and alternative fuels, and simple, low-cost practices such as idle reduction. Currently, there are approximately 15 EPA cleanup sites that are using cleaner diesel technologies and fuels or renewable energy to power their remediation systems.

The Smart Energy Resources Guide (SERG) is a tool for project managers to help them assess and implement these technologies and practices on Superfund sites as well as other cleanup sites. With this information, project managers may be better prepared to discuss emissions reductions strategies with contractors and/or developers. While resources cited in this document focus on Region 9 territories, many are applicable in other parts of the nation.

CHAPTER 1: INTRODUCTION

Remedial actions taken to clean up hazardous waste sites for environmental restoration and potential reuse at U.S. Environmental Protection Agency (EPA) Superfund Program sites are often also sources of harmful greenhouse gas (GHG) and diesel emissions. Region 9 Superfund's Cleanup – Clean Air Initiative (CCA) aims to encourage and facilitate emissions reductions at cleanup sites. The Smart Energy Resources Guide (SERG) was created as part of the initiative to provide information on emissions reductions opportunities for remediation project managers. This information can be useful for ascertaining emissions reductions opportunities at cleanup sites and as background information to facilitate communication with contractors and/or developers about cleaner energy.

Chapter 1 Table of Contents

1.1 Overview of the Smart Energy Resources Guide (SERG)
1.2 The Cleanup-Clean Air Initiative (CCA)
1.3 Incorporating Emissions Reductions Into Site Cleanups
1.4 Importance of Reducing the Superfund Program Environmental Footprint

1.1 OVERVIEW OF THE SMART ENERGY RESOURCES GUIDE (SERG)

The SERG was created for CCA to provide technical information to Region 9 Superfund remedial project managers (RPMs) and to help them make economic decisions about reducing GHG and diesel emissions from energy use in remediation activities at Superfund sites. An optimal phase in which to start considering these actions is during the Remedial Investigation/Feasibility Study (RI/FS) phase of a cleanup. The technical information in this document may assist in designing a remediation system during the Remedial Design/Remedial Action (RD/RA) phase as well. Efforts to reduce emissions can also be applied during remedy system optimization and evaluation, 5-year reviews, and Record of Decision (ROD) amendments. While some information presented in this guide is Region 9-specific, much of the information is also applicable for other parts of the nation. RPM

What the SERG Can Do for You

The SERG provides information on practices and technologies that can reduce emissions from electricity and diesel use at cleanup sites. This information can be used to:

- Assess possibilities of cleaner electricity and diesel at cleanup sites.
- Share information with contractors.
- Provide background information in order to better communicate with contractors and/or developers on emissions reductions strategies.
- Provide a starting point for implementing cleaner electricity and/or diesel projects.
- Reference guide for funding opportunities.
- Reference guide for tools to help estimate costs of technologies and emissions reductions.

counterparts, such as Resource Conservation and Recovery Act (RCRA) site and state project managers, may also find this guide useful.

See Chapter 2 for overviews on energy, conservation and efficiency, general renewable energy, purchasing clean energy, and carbon sequestration. Review Chapter 3 through Chapter 7 for more in depth information on renewable energy technologies that may be applicable for cleanup sites. Chapter 8 provides information on diesel emissions reduction practices and technologies. See Chapter 9 for funding and incentives for energy efficiency efforts, renewable energy projects, and cleaner diesel technologies. Find tools such as calculators, technical resources, and sources of further information for energy efficiency, purchasing clean energy, renewable energy and cleaner diesel in Chapter 10. Calculators to measure emissions and emissions reductions are also included in Chapter 10. In addition, Chapter 10 provides resources to help select a properly licensed renewable energy contractor. Appendix I includes an excerpt of contract language that incorporates CCA principles. Appendix II lists relevant executive orders and federal goals related to emissions reductions. Appendices III-VIII provide supplemental information on renewable energy technologies and cleaner diesel. Find the Region 9 Superfund Electricity and Diesel Emissions Inventory in Appendix IX. Appendix X includes resources to find local utility rate schedules on-line. Appendix XI provides a list of Green Pricing Programs in Region 9 states and territories. Last, Appendix XII provides a summary of some net metering programs in Region 9 states and territories.

The SERG focuses on cleaner energy and cleaner diesel technologies and practices. Although there are many other methods to reduce the environmental footprint of cleanup sites, those strategies extend beyond the scope of this guide.

1.2 THE CLEANUP-CLEAN AIR INITIATIVE (CCA)

The Cleanup – Clean Air Initiative is a cross-program partnership between the EPA Region 9 Air and Superfund Divisions. CCA aims to protect human health by reducing air pollution at Superfund sites during remedial action, construction and redevelopment. CCA seeks to encourage, facilitate and support implementation of diesel emissions and GHG reduction technologies and practices at Superfund cleanup and redevelopment sites. The use of cleaner fuels, retrofit technologies, and idle reduction practices on diesel equipment used at Superfund sites for purposes of construction is consistent with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) section 121(b)(1). In addition, CCA seeks to reduce GHG emissions through better energy management practices, such as the use of renewable energy technologies and improved energy efficiency.

To accomplish the emissions reductions goals, Cleanup – Clean Air:

- Raises awareness of the potential for GHG and diesel emissions reductions at Superfund site cleanup and redevelopment;
- Promotes Cleanup-Clean Air projects by providing coordination and facilitation support for potential projects that reduce diesel and GHG emissions;
- Creates an open forum for information sharing, and works to leverage significant new resources to expand voluntary emissions reductions; and

- Creates momentum for future GHG and diesel emission reduction efforts within the Superfund Program and elsewhere.

Visit the CCA website at www.epa.gov/region9/cleanup-clean-air.

1.3 INCORPORATING EMISSIONS REDUCTIONS INTO SITE CLEANUPS

Some of Region 9 Superfund contracts now include language on cleaner diesel and electricity. The Emergency and Rapid Response Services Contract (ERRS) strongly encourages contractors to use clean technologies and/or fuels on all diesel equipment to the extent practicable and/or feasible. The Response Action Contract (RAC) requires contractors, when directed by EPA, to use cleaner engines, cleaner fuel and diesel emissions control technology on diesel powered equipment where feasible and to evaluate all reasonably feasible renewable energy sources. See Appendix I (page 124) for the incorporated language.

GHG and diesel emissions reductions from cleanup activities can also be achieved through the following mechanisms:

- Modifying the Statement of Work under RAC (completed in Region 9)
- Developing Stand Alone Contract or Interagency Agreements with the Army Corps Of Engineers
  - Request for proposals (RFP) to energy providers
  - General Services Administration schedule

For fund-lead sites, RPMs have more control over which contractors are chosen. If it is lead by a potentially responsible party (PRP), it is best to encourage PRPs to make efforts to reduce diesel and GHG emissions and provide information on emissions reduction technologies and practices.

1.4 IMPORTANCE OF REDUCING THE SUPERFUND PROGRAM ENVIRONMENTAL FOOTPRINT

Reducing GHG and diesel emissions is a high priority for our nation. Presidential executive orders (EOs) and state and federal strategies have stressed the importance of GHG and diesel emissions reductions. For example, the EPA Administrator's Action Plan includes goals to promote diesel emissions reductions and renewable energy development. For a listing of some of the policies, regulations and executive mandates that are driving efforts to reduce emissions, see Appendix II (page 126).

Many remediation systems constructed for Superfund site cleanups operate for decades and/or have high energy consumption levels. Fossil fuel electricity generation is a major source of GHGs, (a primary cause of climate change) as well as other pollutants. Also, remediation activities often include the use of diesel equipment, which consumes fossil fuels and emits toxic diesel exhaust, potentially exposing site workers and surrounding communities.

In the U.S., most electricity is generated from coal or natural gas combustion. Power generation from fossil fuels releases carbon dioxide (CO_2), a GHG, as well as other air pollutants into the atmosphere. In 2005, more than 2.6 billion metric tons of CO_2 were emitted from electricity production in the U.S.[1] The U.S. population is about 300 million, so on average, the nation generated approximately 8.7 metric tons of CO_2 per person due to electricity production in 2005.

A survey conducted of half of Region 9 Superfund sites found that they will emit approximately 428,174 tons of CO_2 from remediation activities between 1990 and 2009 due to electricity consumption. This amount of CO_2 is equivalent to that from 84,000 cars on the road for one year or powering about 50,000 single family homes for one year. From 1985 to 2009, an estimated 3,140 tons of nitrogen oxides (NO_x), 848 tons of carbon monoxide (CO), and 105 tons of particulate matter (PM) will result from diesel equipment use at these sites (DeBoard, EPA GRO Fellow, 2007). See Appendix IX (page 154) for the full report.

CCA seeks to aid the Superfund Program to remediate sites in a manner that minimizes environmental impacts and to set positive examples for the public and other agencies. There are a variety of opportunities for Superfund to reduce GHG and diesel emissions including the following, which are discussed in this guide:

- Energy Efficiency
- Purchasing Clean Energy
- Carbon Sequestration
- Renewable Energy Technologies
- Cleaner Diesel Technologies
- Cleaner and Alternative Fuels

At the time of writing, 15 EPA cleanup sites were identified that currently use renewable energy to power some or all of their remediation activities (Dellens, EPA NNEMS Fellow, 2007).[2] The majority of these sites are utilizing groundwater extraction and treatment systems, one uses soil vapor extraction (SVE), and others are using renewable energy for powering irrigation and data collection purposes. See the EPA publication *Green Remediation and the Use of Renewable Energy Sources for Remediation Projects* (http://cluin.org/s.focus/c/pub/i/1474/) for more details.

CHAPTER 2: ENERGY BASICS, ENERGY CONSERVATION AND EFFICIENCY, RENEWABLE ENERGY INTRODUCTION, PURCHASING CLEAN ENERGY AND CARBON SEQUESTRATION

This section begins with a refresher of electrical and fuel energy basics. It includes information on options to reduce electricity and fuel use and associated environmental impacts. Conservation and energy efficiency opportunities as well as renewable energy are discussed. Purchasing clean electricity is another strategy discussed in this chapter to reduce the unwanted impacts of site cleanups. The end of this chapter includes an overview of carbon sequestration on contaminated lands which may be considered to mitigate GHG emissions.

Chapter 2 Table of Contents

2.1 Understanding Electrical Energy and Key Terms
2.2 Understanding Energy in Fuels and Key Terms
2.3 Energy Conservation and Energy Efficiency
2.4 Renewable Energy Introduction, Net Metering and Utility Bills
2.5 Purchasing Clean Energy
2.6 Carbon Sequestration

2.1 UNDERSTANDING ELECTRICAL ENERGY AND KEY TERMS

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 (Fig. 1).

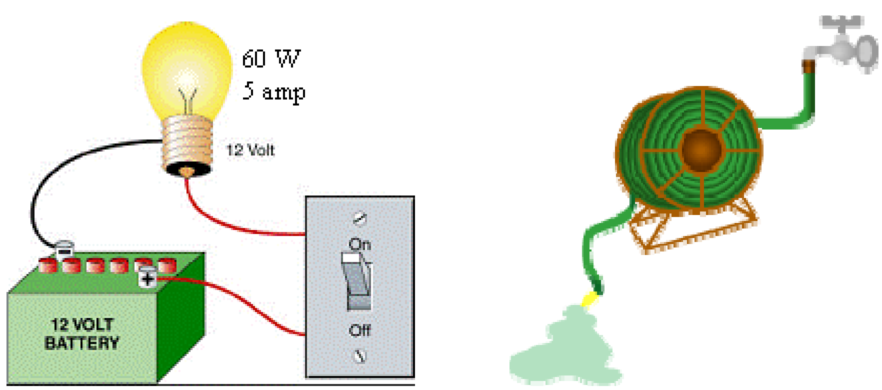

Figure 1 Electric circuit and hose. Image courtesy Solar On-Line and NDT[3]

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 in the hose has and the greater the force with which it is pushed along. Voltage is measured in volts, usually abbreviated "V."[4]

Amperes (Amps) An ampere is a unit of measure of electrical current. An electrical current is the rate at which electrons flow past a given 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."[5]

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). This rate of energy use or production is measured in watts (W). It can also be measured in horsepower (hp). One hp is equivalent to 745.7 W. The power rating is usually found on the specifications of a piece of equipment.

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

One can see the relationships among voltage, amperage and power by returning to the garden hose analogy. A high-pressure garden hose with a pinhole opening will shoot a tiny stream of water far into the air. The water has high energy, but there is very little water actually flowing (high voltage, low amperage). In contrast, consider a large pool of water slowly exiting a very large pipe. There is a large amount of water moving, but it has low energy (low voltage, high amperage). Most modern energy production systems generate both high voltage and high amperage electricity.

Energy Usage The actual energy used is measured in watt-hours (Wh). 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 hours = 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, and so a kilowatt-hour is 1,000 watt-hours. 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 a month.[6] 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.

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

Alternating and Direct Current Electricity needs a complete circuit to flow. Electricity flowing in one direction is referred to as direct current (DC) and is typically found 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.[7]

2.2 UNDERSTANDING ENERGY IN FUELS AND KEY TERMS

Different types of fuels are used to run construction equipment and vehicles, and to produce heat and electricity from renewable energy projects. Heavy-duty equipment like excavators, dozers, drills, and back hoes are used at cleanup sites during removals and construction. Most heavy-duty equipment runs on diesel fuel. Alternatively biogas or syngas fuels are used to generate electricity. Common energy terms associated with fuel include the following:

Biogas Gas produced from the decomposition of organic matter which can be used for heating or electricity generation. Biogas is produced in a landfill or anaerobic digester. See Chapter 5 for information on landfill gas and Chapter 6 for information on anaerobic digesters.

bhp-hr (Brake horsepower – hour) Net power after frictional power losses in the engine are subtracted from the maximum theoretical output power is the brake horsepower. Often seen as g/bhp-hr (grams per brake horsepower-hour) when assessing emissions.

$$\text{Emissions (g)} = \frac{\text{g}}{\text{bhp-hr}} \times \text{bhp} \times \text{hours of operation}$$

BTU (British Thermal Unit) The amount of heat (energy) required to raise the temperature of one pound of water one degree Fahrenheit.[8] Usually refers to energy content in fuels. 3,414 BTU = 1 kWh.

Combined Heat and Power (CHP) Practice of generating electrical and thermal energy and utilizing both, also known as cogeneration. When generating electricity, excess heat is produced and this valuable energy is often wasted. Capturing the thermal energy for heating dramatically increases efficiency.[9]

Energy content The amount of energy that can be released by burning a fuel. See "BTU."

Fuel efficiency/fuel economy Measure of how well chemical energy in a fuel is converted into kinetic energy to operate equipment.

Heat rate Calculated as the fuel energy input divided by the electricity output of prime movers. It is closely related to the efficiency of the electricity generation system. Higher heat rates indicate lower efficiency.

Horsepower (hp) Like watts, a measure of the power required to operate a device or piece of equipment. One hp is equivalent to 0.7457 kW.

Prime Mover Devices that convert fuels to mechanical energy (e.g., gas turbines, reciprocating engines, steam turbines). Biogas or syngas can fuel prime movers to generate mechanical energy which in turn can drive a generator to produce electricity and heat.[10]

Syngas Gas composed of CO and hydrogen (H_2) produced by gasification technologies that can be used for heating and/or electricity generation. See Chapter 7 for information on gasifiers.

2.3 ENERGY CONSERVATION AND ENERGY EFFICIENCY

Conserving energy and improving energy efficiency are the first steps to reducing electricity and fuel use. Energy efficiency efforts reduce pollution and demand on resources, and can save money in many cases. There are many opportunities to improve energy efficiency at cleanup and redevelopment sites.

Conservation and Increasing Efficiency in Equipment

While preserving the priority of remediating a contaminated site to cleanup levels specified in the ROD, energy conservation may be considered during remedy selection. In long-term remedial action, remediation equipment may operate for years and even decades. In order to reduce energy demand as well as wear, equipment should be purchased and maintained for maximum efficiency. Although a piece of equipment may be over-sized in order to compensate for infrequent unexpected loads, note that the piece of equipment may not run at its maximum efficiency for the majority of operation. For example, a 50-hp pump engine may be very inefficient running at 30 percent of its full power. Installing a 15-hp engine instead can reduce energy bills compared to running the 50-hp engine at low power.[11] Properly sizing and maintaining pumps will prevent electricity and money from being wasted and will reduce pollution. Compare efficiency curves of pumps and purchase/rent a motor that is just powerful enough to meet what is required.

See *Introduction to Energy Conservation and Production at Waste Cleanup Sites* (www.epa.gov/swertio1/tsp/download/epa542s04001.pdf), a May 2004 EPA Engineering Forum Issue Paper for details on opportunities to make your pumps more efficient.

The same concept applies to diesel engines used during cleanup. Diesel fuel is wasted when oversized equipment is used to perform a job that a smaller piece of equipment is better suited to complete.

Optimizing Electricity Use Schedules

Utilities often resort to alternate, more expensive, polluting sources of energy during times of high-demand such as summer daytime hours. Time-of-use (TOU) rate schedules often categorize these times as "on-peak" hours. Under TOU schedules, electricity prices during on-peak hours are often significantly higher than during mid-peak or off-peak hours. Reducing electricity use at your site during on-peak hours can help to minimize the need for utilities to operate beyond their base loads and can reduce your utility bill. If available, contact an account manager at your utility to help compare different rate schedules to see which one best suits the electricity demands of your site in order to reduce costs. See Appendix X (page 172) for a list of web pages where you can find rate schedules for many utilities providing service in Region 9 states and territories.

2.4 RENEWABLE ENERGY INTRODUCTION, NET METERING AND UTILITY BILLS

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 power, wind power, landfill gas-to-energy projects, anaerobic digestion and biomass gasification. Other renewable energy technologies such as hydropower, geothermal, tidal power, and biomass direct-combustion and pyrolysis are not covered in this guide. See Table 1 for a chart that summarizes applications and costs of some of these technologies. Cleanups may require a high electricity demand. Using renewable energy can avoid many of the pollutants emitted from fossil fuel use, including GHGs. Renewable energy use also reduces the demand to extract fossil fuels. Solar and wind power are widely available resources and the technologies are well established. Cleanup sites that are near landfills may consider capturing landfill gas if available. Sites that have potential biomass resources nearby may consider anaerobic digesters or gasifiers to produce electricity. Solar and wind options also require less maintenance and operational costs compared to digesters and gasifiers.

Additionally, implementing a renewable energy project can reduce energy bills. Some utilities have net metering programs which can increase monetary savings. Net metering programs allow grid-tied utility customers who generate electricity in excess of their consumption to credit that amount for later use.[12] For example, when a wind turbine produces more electricity than is consumed on-site, excess electricity is sent to the grid. For net metered systems, the utility acts like a giant battery. When wind power is unavailable, the site can use the energy credits from the utility. Some utilities may purchase excess power generated from renewable energy projects. Not all utilities have a net metering program. See Appendix XII (page 176) for net metering programs in Region 9 territory.

Also, review the cleanup site's energy bill to become familiar with how it is charged for electricity use. Commercial and agricultural customers are often charged per kWh (the electricity actually consumed), as well as per kW (the power the utility needs to have available). This kW charge is based on the highest level of power demanded during the month. This charge is often a large portion of the bill and may also be difficult to avoid. It may be worth sizing a renewable energy system for the purpose of reducing the demand charge.

Table 1 Summary of Some Renewable Energy Applications and Costs[13]

Energy Source	Applications	Cost (Generating Capacity)	Cost (Use)	U.S. Production
Solar	P&T, SVE, data collection, general energy production	$8-$10 per watt	$0.04-$0.07 per kWh	120 MW (PV)
Wind	P&T, SVE, general energy production	$2-$4 per watt	$0.20-$0.30 per kWh	11,961 MW
Landfill gas	General energy production	$2-3 per watt	$0.07-$0.09 per kWh	1,195 MW

2.5 PURCHASING CLEAN ELECTRICITY

While it may not be feasible for a cleanup and redevelopment site to produce its own renewable energy, there are other options for a site to offset its carbon emissions from energy use. Options include buying Renewable Energy Credits and participating in green pricing programs. To estimate emissions reductions from purchasing clean electricity, go to EPA's Power Profiler listed in Chapter 10 (page 112.)

Renewable Energy Credits

Renewable Energy Credits (RECs), also called Renewable Energy Certificates or Green Tags, represent the environmental benefit from producing energy from renewable resources separate from the actual electricity. A REC puts a dollar value on the environmental benefits of clean energy that can be traded and sold independently of any actual electricity. After the REC is sold, the clean energy producer sells renewable electricity at the market price for conventional electricity. For example, producers of renewable energy, such as wind farm owners, register the amount of electricity they produce and can receive RECs. They can in turn sell two different products, electricity and RECs, to two different customers. REC owners can claim that they have offset their emissions from fossil fuel electricity consumption with cleaner renewable energy. The EPA purchases RECs to offset 100 percent of its energy use in EPA facilities nationwide. For a list of REC retailers, go to www.eere.energy.gov/greenpower/markets/certificates.shtml?page=1.

Green Pricing Programs

Some utilities provide green pricing as an optional service. These options provide an opportunity for customers to support the utility company's investment in renewable energy technologies. Participating customers pay a premium on their electric bills to cover the additional cost of renewable generation relative to conventional generation. More than 600 utilities in the nation, including investor-owned, municipal utilities, and cooperatives, offer a green pricing option. The price premiums charged in green pricing programs range from 0.7 cents per kWh to as much as 17.6 cents per kWh. Contact your utility to see if they offer a green pricing program. See Appendix XI (page 174) for some green pricing opportunities in EPA Region 9 states and territories.

Power Purchase Agreement

Another option for using renewable energy is to enter into a power purchase agreement (PPA). A PPA is a long-term agreement to buy electricity from a power producer. A company that provides PPA services will use its own funds to install a renewable energy system on your site. The company will own the system and sell the produced power to provide the needed power for your remediation system. This type of agreement may be applicable for the renewable energy technologies discussed in this document. PPAs may also be considered if a renewable energy project on a cleanup site produces a surplus of energy that can be sold to another party. For more information, go to EPA's *Guide to Purchasing Green Power* pages 22-23 (www.epa.gov/greenpower/documents/purchasing_guide_for_web.pdf).

2.6 CARBON SEQUESTRATION

Carbon sequestration is the process of removing CO_2 from the atmosphere and storing it in another form. Carbon can be stored in plant-life, soils, and geologic formations. While CO_2 can be sequestered in geologic formations such as oil and gas reservoirs, un-mineable coal seams, and deep saline reservoirs, this section focuses on carbon sequestration in plants. Restored lands may provide space for carbon sequestration in plant matter. Plants remove CO_2 from the atmosphere and store it in biomass (Fig. 2).[14] Plants store CO_2 in their tissues and also release some CO_2 back into the atmosphere. Soils also store and release CO_2. Net sequestration results if the rate of removal is higher than the rate of release. Young, fast-growing trees in particular will remove more CO_2 from the atmosphere than they will release.[15] An informational and technical resource is the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) which is currently researching carbon sequestration on mined lands[16] (www.netl.doe.gov/technologies/carbon_seq/index.html).

Carbon sequestration rates vary by tree species, soil type, regional climate, topography and management practice. In the U.S., fairly well-established values for carbon sequestration rates are available for most tree species. Soil carbon sequestration rates vary by soil type and cropping practice and are less-well documented but information in this area is growing.[18]

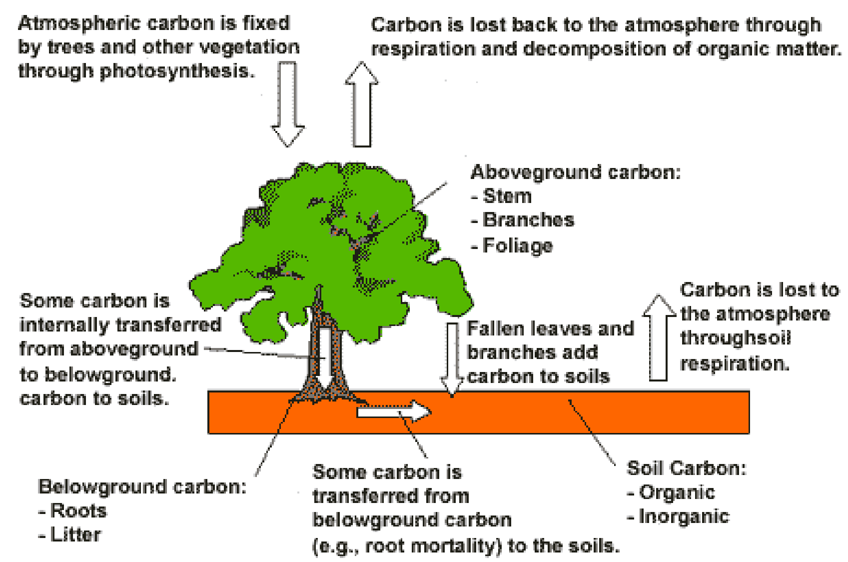

Figure 2 Carbon sequestration in plant-life. Image courtesy EPA[17]

Planting trees on lands previously not forested is called *afforestation*, which may be feasible for some cleanup sites. Afforestation can sequester about 0.6–2.6 metric tons of carbon per acre per year for approximately 90-120 years.[19] Carbon accumulation in vegetation and soils eventually reaches a saturation point. This happens, for example, when trees reach maturity, or when the organic matter in soils builds back up to original levels before losses occurred. Even after saturation, the trees or agricultural practices need to be sustained to maintain the accumulated carbon and prevent subsequent losses of carbon back to the atmosphere.[20]

Use the following document to estimate the amount of carbon sequestered in trees at your site: *Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings* by the DOE, Energy Information Administration (EIA) published in April 1998 (ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/sequester.pdf).

For more information go to:

- EPA Carbon Sequestration Web Pages: General information on carbon sequestration in agriculture and forestry. www.epa.gov/sequestration
- DOE Carbon Sequestration Web Pages: Information on DOE carbon sequestration efforts. www.fossil.energy.gov/programs/sequestration
- NETL Carbon Sequestration Web Pages: Information on current carbon sequestration research. www.netl.doe.gov/technologies/carbon_seq
- *The Contribution of Soils to Carbon Sequestration* (Plains CO_2 Reduction Partnership, August 2005): Document detailing soil carbon sequestration. www.netl.doe.gov/technologies/carbon_seq/partnerships/phase1/pdfs/ContributionSoils.pdf
- West Coast Regional Carbon Sequestration Partnership: This partnership is a collaborative research project bringing together dedicated scientists and engineers at 70 public agencies, private companies, and nonprofits to identify and validate the best regional opportunities for keeping CO_2 out of the atmosphere. www.westcarb.org/

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CHAPTER 3: SOLAR POWER

Various technologies are available to capture energy from the sun. Photovoltaic (PV) technology converts solar energy directly to electrical energy. In addition, heat from the sun can be used in solar hot water heaters or in concentrated solar power modules (see Appendix III page 134). While other forms of solar power are available, this guide focuses on PV technology. The Pemaco Superfund site in southern California is currently augmenting some of its grid-power consumption with a 3-kW solar PV system (see Section 3.7). PV systems typically require little maintenance depending on the complexity of the system.

Chapter 3 Table of Contents

3.1 Solar Power Terminology
3.2 Solar Power Technology Basics
3.3 Assessing Solar Power Potential and Size of a PV System
3.4 Grid-Tied or Stand-Alone Systems
3.5 Capital Cost, O&M, Installers and Warranties
3.6 Permits and Environmental Concerns
3.7 Success Stories

3.1 SOLAR POWER TERMINOLOGY

The following are some solar power terms and definitions. See Appendix III (page 128) for more terms.

Photovoltaic (PV) Solar power technology that converts light energy into electrical energy.[21]

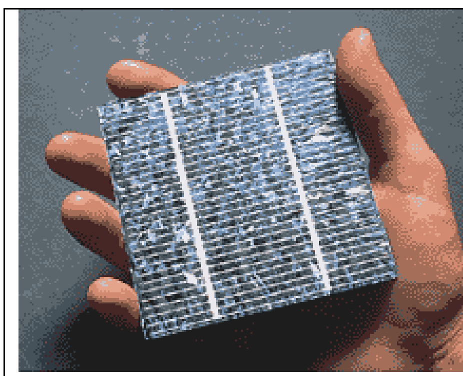

Figure 3 Multi-crystalline solar cell. Image courtesy Lawton Ltd[22]

PV Cell Smallest semiconductor element within a PV module to perform the immediate conversion of light into electrical energy. They are also referred to as solar cells (Fig. 3).[23]

PV Module Individual PV cells wired together in a sealed unit is called a module. It is the smallest assembly of solar cells and additional parts, such as interconnections, intended to generate DC power.[24]

PV Panel A group of modules wired together.[25]

PV Array PV system component composed of one or more PV modules or panels wired together. The array is an interconnected system of PV modules that function as a single electricity-producing unit.[26]

Battery A device that stores electricity for use when the PV system is not providing enough energy to meet the demand.[27] Typical batteries for PV systems last for 5-10 years.[28] See Appendix III (page 130).

Charge Controller A device that prevents overcharging of the batteries and the batteries from overly discharging electricity.[29] See Appendix III (page 132).

Inverter A device that changes direct current (DC) power to alternating current (AC). Electricity produced by the PV system is DC, and stored as DC if batteries are used, but appliances and equipment usually use AC power. The inverter converts DC electricity to AC either for stand-alone systems or to supply power to an electricity grid.[30] See Appendix III (page 132).

Balance of System Term used to describe PV system parts that include all hardware such as wiring and safety equipment that keep the system functional.[31]

Net Metering Net metering programs allow grid-tied utility customers who generate electricity in excess of their consumption to credit that amount for later use.[32] See Appendix XII (page 176) for some net metering programs in Region 9 states.

3.2 SOLAR POWER TECHNOLOGY BASICS

Sunlight hits PV cells and creates an electrical current. PV systems generate electricity without noise nor pollution (although production of PV systems results in some emissions, see Section 3.6) and are widely available. PV systems have a useful life of at least 25 years until the unit produces power at 80 percent of its original power rating.[35] PV technology can be installed in areas with sufficient space and solar resource. The core component of a solar panel is a PV cell. A PV module is made up of individual PV cells wired together in a sealed unit. An array is made up of interconnected modules (Fig. 4).

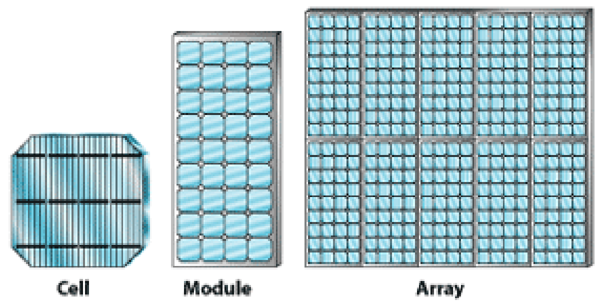

Figure 4 PV cells are interconnected into a module, and modules are interconnected to form an array to increase power output. Image courtesy EERE[33]

PV cells are composed of at least two layers of semiconductor material, commonly silicon. Sunlight hitting the cell causes electrons to flow in a single direction, generating DC electricity (Fig. 5). An inverter is then needed to convert the electricity to AC. See Appendix III (page 128) for more information on PV technology. You can view a short video by DOE's Office of Energy Efficiency and Renewable Energy (EERE) at the following link to see how a solar cell converts sunlight into electricity: www1.eere.energy.gov/solar/animations.html.

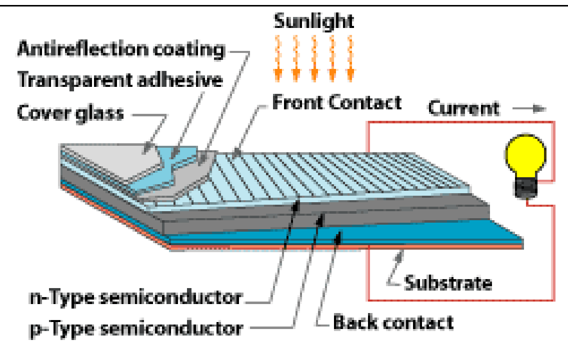

Figure 5 Inside a solar PV cell. Image courtesy EERE[34]

Crystalline and Amorphous Modules

Current cutting-edge PV technology can convert up to 40 percent of solar energy that hits a PV panel into electricity. Most readily available crystalline PV systems have solar cells with efficiencies of around 10-15 percent. Amorphous PV cells, or thin-film technology, have maximum efficiencies of about 10 percent. They are ideal for building-integrated uses such as roof tiles or shingles (Fig. 6).[36] Advancing technologies show that they may soon produce electricity at rates almost as high as crystalline modules and may drastically bring down the cost of solar power.[37]

Single-crystalline PV devices are made from a single large silicon crystal. Multi-crystalline modules are made from multiple crystals grown together and are slightly less efficient than single-crystal modules. Amorphous modules are manufactured by depositing semi-conductor material onto a sheet of glass or plastic. Crystalline modules are delicate and need to be mounted on a rigid frame. Amorphous modules are flexible and their efficiency is not as affected as crystalline varieties by high temperatures, shading or cloudy days. While 100 ft^2 of crystalline cells produce roughly 1 kW, 100 ft^2 of amorphous cells will produce about 0.60 kW.[39]

Estimating Solar Power Emissions Reductions Using FindSolar.com and EPA's Power Profiler
www.epa.gov/cleanenergy/powerprofiler.htm

Consider the Pemaco Superfund site as an example. FindSolar.com estimates that a 3-kW solar system in southern California produces about 375 kWh per month. Then, go to the Power Profiler and enter the required information. Under "Make a Difference," select "My Emissions." Enter 375 kWh into the "Average Monthly Use" option. The Profiler estimates that about 4,311 pounds of CO_2 are released annually from producing 375 kWh of conventional electricity each month. This means that the 3-kW PV system at Pemaco prevents an estimated 4,311 pounds of CO_2 from being released into the atmosphere every year.

Figure 6 Building integrated PV (BIPV) shingles. Image courtesy Kyocera[38]

Tracking or Fixed Tilt

Tracking units point the modules at the optimal angle to the sun throughout the day (Fig. 7). They can increase efficiency by 15 percent in the winter and 40 percent in the summer and thus can reduce the size of the system but require significant additional costs. They may need more frequent maintenance due to 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 degree of latitude of the site to capture the greatest amount of energy over the year without using a tracking system.[41]

Figure 7 Solar tracking unit. Image courtesy Northern Arizona Wind and Sun[40]

3.3 ASSESSING SOLAR POWER POTENTIAL AND SIZE OF A PV SYSTEM

Sites that receive direct sunlight without shading from 9 am to 3 pm have good solar power potential. The following DOE National Renewable Energy Laboratory (NREL) website provides maps of solar radiation (sunlight availability) based on location and solar mounting type (fixed tilt or tracking) (Fig. 8): http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/atlas/. Keep in mind that this website gives the actual total solar radiation hitting earth's surface. Solar modules are 10-15 percent efficient at capturing this energy.

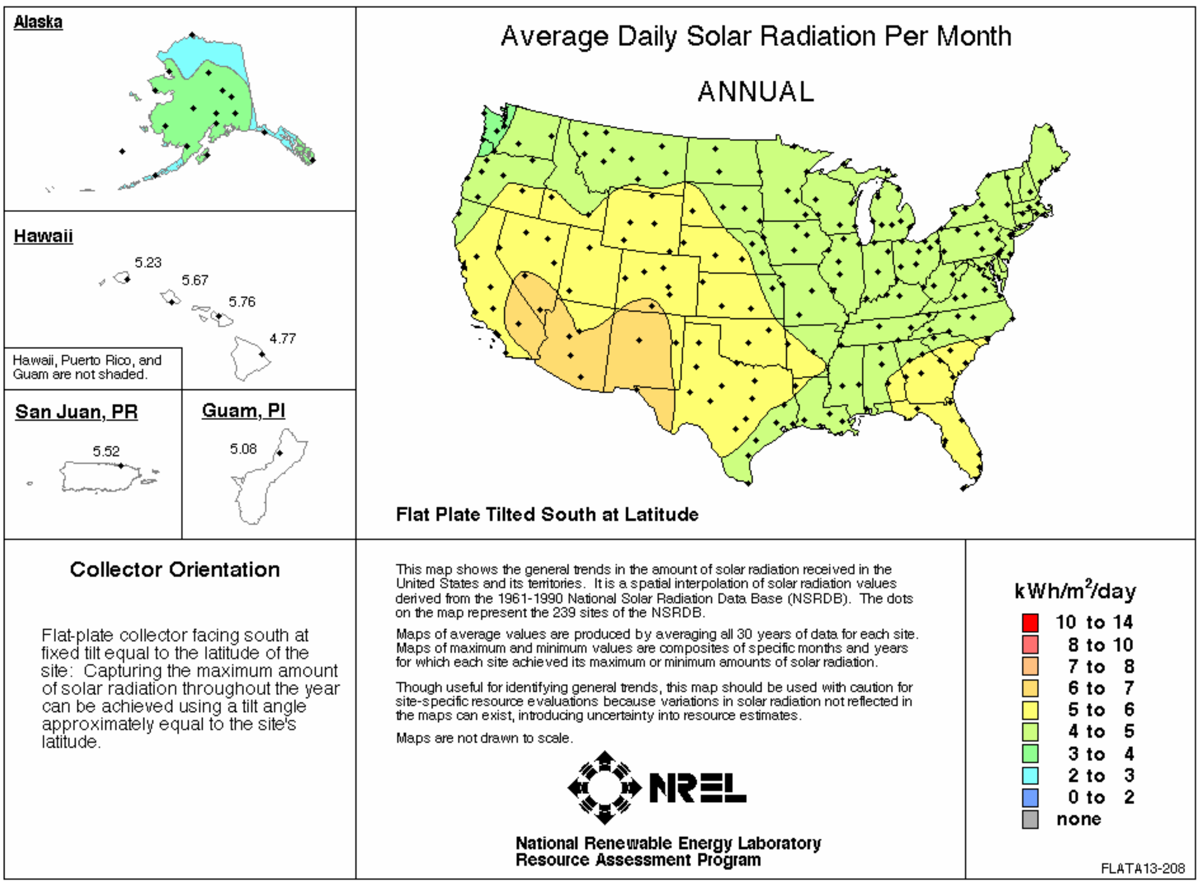

Figure 8 Solar radiation map. Image courtesy NREL[42]

PV panels can provide power to cleanup 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.

Completely shading just one cell can reduce efficiency by 75 percent for crystalline systems.[43] On moderately cloudy days, arrays can produce 80 percent of electricity compared to a bright sunny day, and on highly overcast days they can produce 20 percent.[44] For sites in the northern hemisphere, PV panels should be south-facing for maximum sunlight exposure. East or west facing panels may also be acceptable.[45] Panels can be mounted on roofs or poles or directly on the ground.

A PV system can be sized to meet all or a portion of your site's energy consumption. The size of the PV system needed for a site depends on the energy demands of the remediation system 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 power output in laboratory conditions. A more accurate efficiency rating is the PV-USA Test Conditions rating which reflects the output under day-to-day conditions. A PV system rated for 1-kW in Region 9 sites will typically produce between 135 and 150 kWh per month. See EERE's *A Consumer's Guide: Get Your Power from the Sun* page 9 for a map of estimated site-specific annual solar energy production (www.nrel.gov/docs/fy04osti/35297.pdf). Rated kW is the maximum output capacity of the PV system. The actual energy produced depends on the solar resource at the site and efficiency of the PV equipment. Use the following equation (Box 1) to estimate the size of a PV system needed. To estimate your energy needs per month for a remediation system that is already operating, look at the site's energy bill for the number of kWh used per month. See Section 10.5 (page 114) for calculators to help size a solar PV system for the needs of your site.

Box 1 Size Calculation for a Simple PV System

$$S = E \div O$$

S = PV System Rated Power Output (kW)

E = Site Energy Needs per Month (kWh per month)

O = Average PV Energy Output (kWh per kW per month); Estimate 135 kWh/kW/month

3.4 GRID-TIED OR STAND-ALONE SYSTEMS

As previously discussed, grid-tied systems are connected to a utility grid. Stand-alone systems are not connected to a grid and may need battery backup or another source of power (e.g., clean diesel generator or wind turbine hybrid system) if a constant source of energy is necessary. Batteries add a substantial cost to a PV system but may be economical considering the cost of extending power lines. Evaluate the available electricity infrastructure in addition to solar energy availability.

Stand-Alone Day Use with DC Load

These systems are the simplest and least expensive. This configuration is applicable for remote sites that do not require a steady supply of power, especially at night. Examples include solar powered remote water pumps and solar powered fans used to circulate air in the daytime. Remediation equipment, devices or appliances that operate on DC power can directly use the electricity produced from the solar panels (Fig. 9).[47]

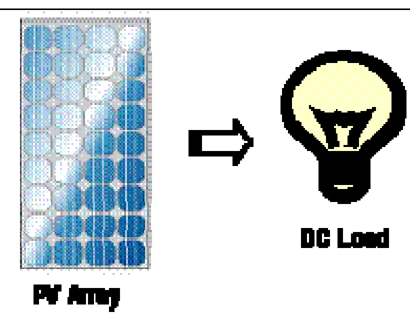

Figure 9 Day use DC load. "PV Array" image courtesy Solar On-Line[46]

Stand-Alone DC Load with Batteries

In many cases, electricity is needed in the day as well as at night and during cloudy weather. Excess energy produced during the day is stored in a battery to be used when the solar resource is not available. Battery power can also be used to provide high surge currents for short amounts of

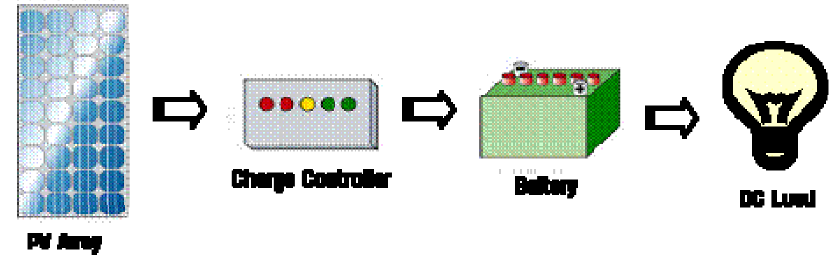

Figure 10 Stand-alone DC load with batteries. Separate images courtesy Solar On-Line except "DC Load"[48]

time which may be useful to start large motors. To prevent the battery, or batteries, from being overcharged or overly discharged, a device called a charge controller must be installed (Fig. 10).[49] See Appendix III (page 132) for more information on charge controllers. PV systems with batteries cost about $15,000-$20,000 per kW.[50]

Stand-Alone AC Load with Battery

When solar panels are used to power AC loads, an inverter is installed to convert solar DC power to AC power (Fig. 11). Though inverters add complexity and cost, their use usually cannot be avoided. AC appliances are mass produced and more reliable than DC appliances. To see if your load is AC or DC, check manufacturer specifications.[51]

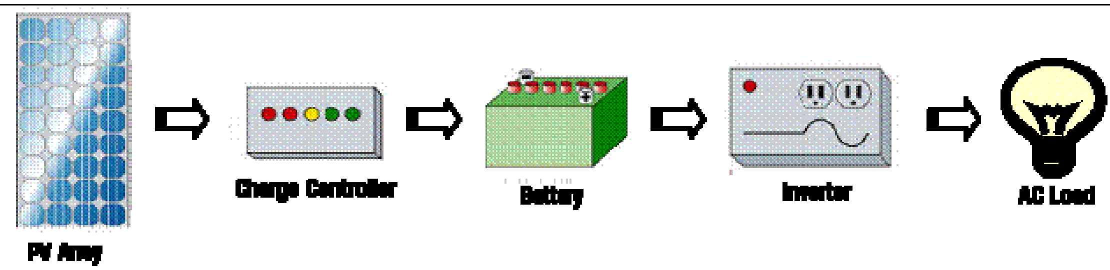

Figure 11 Stand alone AC load with battery. Separate images courtesy Solar On-Line except "AC Load"[52]

Grid-Tied AC Load

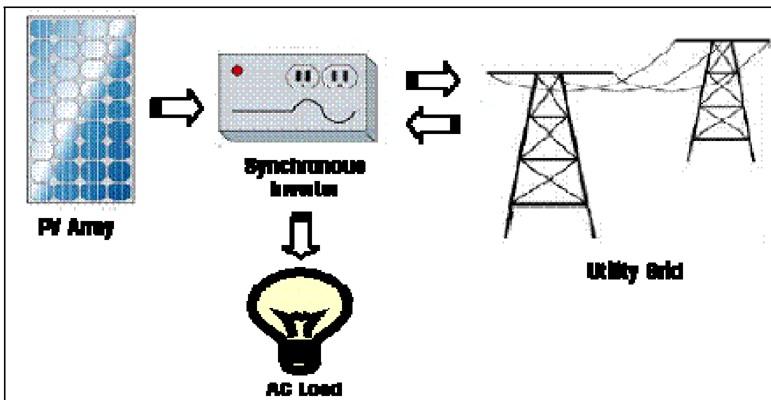

Figure 12 Grid-tied AC load without battery. Image courtesy Solar On-Line except for "AC Load"[53]

Grid-tied systems are interconnected with the utility grid (Fig. 12). When energy consumption exceeds energy production, the grid provides the remaining electricity needed. At times when electricity production is greater than consumption, excess energy is sent to the utility grid. Utilities may have a net-metering program that gives credits for electricity sent to the grid. See Appendix XII (page 176) for net metering rules in your area. Also, without a battery, if the grid goes down, the site will not be able to get electricity from your solar PV system. They are disconnected at these times so utility employees are not at risk from an unexpected "live" wire.[54] Contact the local utility for more information on connecting to the grid.

Grid-Tied AC Load With Battery

Grid-tied systems can still have battery backup to help reduce demand from the grid. Excess energy generated will charge the battery, or batteries. If there is more energy left over, it will run back to the grid. In case the PV and battery system cannot meet the demand, the grid will provide necessary electricity. Also, these systems can operate when grid electricity is unavailable.

3.5 CAPITAL COST, O&M, INSTALLERS AND WARRANTIES

Estimate Capital Cost

The capital costs of a PV system with battery backup is $15,000-$20,000 per rated kW ($15-$20 per watt). PV systems without batteries cost $8,000-$10,000 per rated kW ($8-$10 per watt) (Box 2).[55] See Section 10.5 (page 114) for calculators to estimate initial costs, cash flow, and energy production.

Box 2 Capital Cost Calculation for a Simple PV System
C = S ∗ P
C = Capital Cost of PV System ($)
S = PV System Rated Power Output (kW)
P = Price per kW of PV System ($ per kW); Estimate $10,000/kW

Operations and Maintenance

Panels should be cleaned once a year if the cleanup site receives little rain and/or wind or has substantial bird populations. The PV equipment manual should provide more information on maintenance of the system and its components. 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. Inverters usually need replacement after about 15 years of operation. Cost for inverter replacement is about $700 per rated kW.[56] If your system has batteries, they need to be replaced every 5-10 years.[57] It is important to allow air flow under and over the modules to remove heat and avoid high cell temperatures. A module will lose approximately 0.5 percent efficiency per degree centigrade temperature rise between 80˚C and 90˚C.[58] The output of a PV module degrades by about 0.5 percent per year.[59] Annual operations and maintenance costs are around 0.25-1.5 percent of the initial capital cost.[60] Estimate total operations and maintenance costs for the life of the solar system with the equation in Box 3.

Box 3 Lifecycle Operation and Maintenance Costs
O&M = P ∗ C ∗ Y
O&M = Total Lifecycle O&M Costs ($)
P = 0.0025 for low estimate; 0.015 for high estimate
C = Capital Cost of PV System ($)
Y = Years of operation (years); Estimate 25 years

Solar Installers

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, wiring, batteries, mounting, and any other equipment for a full running system. Here are a few websites that provide information on solar installers:

- Findsolar.com: Pre-screened, customer reviewed installers. www.findsolar.com Select "Find a Solar Pro."
- Solar Energy Industries Association Members: National solar trade association. www.seia.org
- General Services Administration Contracts Schedule: www.gsaelibrary.gsa.gov Search "206 3" for solar businesses.
- Source Guides: Renewable energy businesses and organizations directory. www.sourceguides.com

Start with contractors local to the site since they would be familiar with the weather, sun availability, and permitting processes for the area. Make sure that they are licensed (Section 10.4 page 114). Research or interview the companies with some of the following questions.[61] For a more extensive list of questions for your potential installer, see Appendix III (page 133).

- How many projects like yours have they completed in the past year? In the past three years?
- Can they provide a list of references for those projects?
- What PV training or certification do they have?
- Do they offer adequate warranties?
- Can you communicate effectively with the contractor?

Warranties[62]

More expensive solar panels may include a 20-25 year warranty. However, this warranty will not likely apply to all system components. The parts and labor warranty will usually cover two years, in addition to the regular manufacturer's warranty. Batteries typically have limited warranties ranging from 8-10 years. Inverters will usually have a two year warranty.

Be sure of the following:

- Is your warranty included in the cost of the bid, or do you know its cost?
- Does the warranty cover all aspects of the removal, shipping, repair and reinstallation of components?
- Who is responsible for all aspects of the system--is it the installer, the manufacturer, the dealer?

3.6 PERMITS AND ENVIRONMENTAL CONCERNS

Permits

Installers are usually responsible for garnering permits from city and/or county offices and will pass on these costs to the customer.[63] 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.[64] 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.

Environmental Concerns

The following addresses some PV system environmental concerns.

How long does it take for a PV system to recover the energy that went into producing it?

DOE estimates that today's multi-crystalline silicon PV systems have about a four year energy payback period while it takes three years for current thin-film modules, two years for future multi-crystalline modules, and one year for anticipated thin-film modules.[65]

What happens to panels after their useful life?

PV systems have about a 25-30 year useful life so there currently is little issue with its disposal. PV products are generally safe for landfills because PV materials are usually encased in glass or plastic, and many are insoluble. Some modules, however, may be classified as hazardous waste due to small amounts of lead solder, selenium and cadmium.[66] This is prompting the PV industry to develop recycling processes for modules. Recycling processes may even allow some PV components to be recovered intact. This in turn would allow companies to produce recycled PV modules at a lower cost and with lower energy use.[67]

3.7 SUCCESS STORIES

The following are three success stories of Region 9 Superfund sites that are using solar PV systems.

Figure 13 3-kW solar PV system at Pemaco. Image courtesy Caraway[68]

Pemaco Superfund Site, Maywood, CA, Region 9

Pemaco is a fund-lead Superfund site located in southern California in the city of Maywood. It is a former chemical mixing plant and EPA determined that the soil and groundwater on site were contaminated with volatile organic compounds (VOCs) including perchloroethylene (PCE), trichloroethylene (TCE), trichloroethane (TCA), dichloroethane (DCA), and vinyl chloride. A 3-kW solar system was installed on the roof of the building that houses remediation equipment (Fig. 13). It will provide some of the electricity demanded for the site. The PV panels were installed and operational as of June 29, 2007, and power was being directed back into the utility grid. The PV system will produce an estimated 375 kilowatt hours per month (4,506 kilowatt hours per year) and will avoid 4,311 pounds of CO_2 per year, four pounds of NO_x per year, and three pounds of sulfur dioxide (SO_2) per year.

Site Contact:
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RPM, EPA Region 9
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Apache Powder Company Superfund Site, St. David, AZ, Region 9

The Apache Powder Company Superfund site is a former industrial chemicals and explosives manufacturing plant. Contaminants identified on-site include high concentrations of heavy metals in ponds, arsenic, fluoride and nitrate in perched groundwater, dinitrotoluene in a drum disposal area, and nitrate in shallow wells. The perched groundwater zone is pumped and treated by forced evaporation (brine concentrator). The shallow aquifer is pumped and treated with the use of constructed wetlands. The treated water is then pumped back into the aquifer. Solar power is used on site to power a pump that recirculates water through the wetlands when the water cannot be discharged to the aquifer (when water exceeds nitrate discharge limit of 30 parts per million [ppm]). The PV system consists of twelve PV panels with a 1,440 watt total capacity and one solar powered centrifugal pump. The system is capable of pumping five gallons per minute through 100 feet of two inch fire hose with an elevation rise of about 10 feet. The system is only used when sunlight is available.

Site Contacts:
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Greg Hall
Apache Nitrogen Products, Inc.
E-mail: ghall@apachenitro.com

Lawrence Livermore National Laboratory Site 300 Superfund Site, Eastern Altamont Hills near Livermore, CA, Region 9

The Lawrence Livermore National Laboratory Site 300 is an 11 square mile facility operated by the University of California System for DOE as a high explosives and materials testing site for nuclear weapons research, established in 1955. Groundwater contaminants released from various on-site activities include solvents, VOCs, tritium, uranium-238, highly explosive compounds, nitrate, and perchlorate. Sources of contamination include spills, leaking pipes, leaching from underground landfills and pits, high explosives testing and disposal of waste liquids in lagoons and dry wells. A groundwater P&T system is operating to treat contaminated groundwater at four locations. Solar power is used to pump water through four granulated activated carbon (GAC) systems. The systems were installed between June 1999 and September 2005. The low flow systems pump groundwater at about 5 gallons per minute from depths of 75-100 feet. Each system has a capacity of 800 watts (for a total of 3.2 kW) and costs about $2,000. These systems are not grid connected but they are equipped with batteries to store excess power to allow for some operation during non-daylight hours.

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CHAPTER 4: WIND POWER

Wind is a renewable energy resource that can be captured to produce electricity. Wind turbines convert kinetic energy from wind into mechanical energy (Fig. 15). Generators then convert this mechanical energy into electrical energy that can be used anywhere, including on a cleanup site. An average wind speed of at least 10 miles-per-hour (mph) at 33 feet above the ground is typically necessary to run a wind turbine. An example of a Superfund site utilizing wind power is the Nebraska Ordnance Plant Superfund Site. It currently has a 10-kW wind turbine powering its groundwater circulation wells (see Section 4.7).

Chapter 4 Table of Contents

4.1 Wind Power Terminology
4.2 Wind Power Technology Basics
4.3 Assessing Wind Power Potential and Sizing a Wind Turbine
4.4 Grid-Tied or Stand-Alone Systems
4.5 Capital Costs, O&M, Permits, Insurance and Environmental Concerns
4.6 Finding Wind Turbine Vendors and Installers
4.7 Success Story

4.1 WIND POWER TERMINOLOGY[69]

The following are some wind power terms and definitions (Fig. 14).

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

Blades Most turbines have either two or three blades. Wind blowing over the blades causes the blades to "lift" and rotate.

Controller Component of a wind turbine that starts up the rotor in 8-16 mph wind 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 a wind turbine and produce electricity. Varies from turbine to turbine.

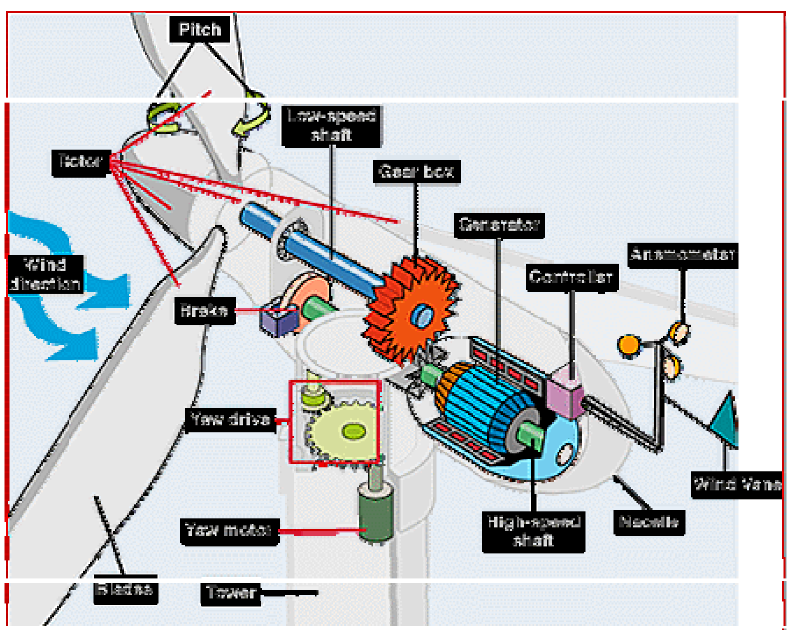

Figure 14 Parts of a wind turbine. Image courtesy DOE, EERE[70]


Figure 15 A 5-kW wind turbine. Image courtesy ISET[71]

Cut-out Speed Maximum wind speed that a turbine can handle. Turbines automatically stop spinning at winds speeds 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).

Inverter Small wind turbines (20 W–100 kW) usually produce DC power. Inverters convert DC power to AC power so it can be used to power AC equipment.[72] See Appendix III (page 132) for more details.

Low-speed Shafts Drive 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.

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.[73] Swept Area = $\pi \times r^2$ (r = length of one blade; $\pi \approx 3.14$)

Tower Vertical structure made from tubular steel or steel lattice. Because wind speed increases with height, taller towers enable turbines to capture more energy and generate more electricity than turbines mounted on shorter towers. See Appendix IV (page 135).

Wind Power Class NREL wind speed and corresponding wind power classification system (Table 2).

Wind Power Density Available power usually measured in watts per square meter (Table 2).

Wind Direction Figure 14 illustrates an "upwind turbine", so-called because it operates with the blades facing into the wind. Other turbines are designed to run downwind, with the blades facing away from the wind.

Wind Map Map showing average annual wind speeds at a specified elevation (Fig. 20 page 30).

Wind Vane Component of a turbine that 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 Component of a turbine that keeps the rotor facing into the wind as wind direction changes.

4.2 WIND POWER TECHNOLOGY BASICS

Kinetic energy in wind can be captured by wind turbines and converted to mechanical energy. Generators produce electricity from the 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 in a turbine to create electricity (Fig. 16). Remediation systems used to pump groundwater may consider windmills that directly draw water, rather than turbines for producing electricity. Windmills are commonly used on farms and have been utilized for hundreds of years.[76]

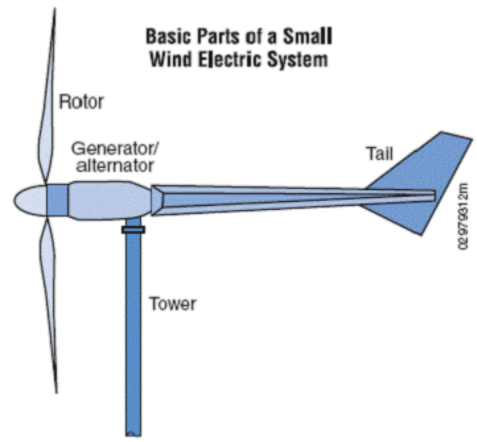

Figure 16 Main parts of a wind turbine. Image courtesy EERE[74]

Wind turbines range in size from a few hundred watts to as large as several megawatts (Fig. 17).[77] The amount of power produced from a wind turbine depends on the length of the blades and the speed of the wind. The faster the wind speed, the more kinetic energy it has. See Appendix IV (page 135) for more information on energy in wind. 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 the 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 (Appendix IV page 135). A common tower height is about 150 feet though it will depend on the length of the blades. A 10-kW turbine is usually mounted on a tower of 80-120 feet.[78]

Figure 17 3.6 MW turbine. Image courtesy EERE[75]

NREL divides wind speeds into wind power classes designated Class 1 (lowest) through Class 7 (highest) (Table 2). Class 2 and above wind speeds (at least 10 mph at 33 feet above ground) can provide sufficient energy to drive a small wind turbine. Utility sized turbines usually need at least Class 3 wind conditions to operate.

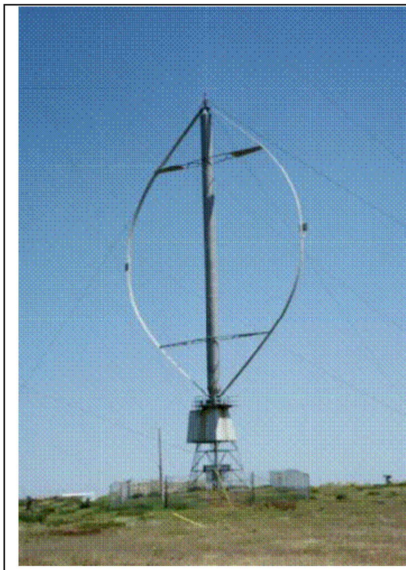

Figure 18 Darrieus style wind turbine. Image courtesy Solcomhouse[80]

Table 2 Wind Power Classes at 10 m (33 ft) Elevation*[79]

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

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 (Fig. 18). Blades for both types of turbines are made from fiberglass, carbon fiber, hybrid composites, or wood and will not interfere with television or radio waves.[81]

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. Large turbines are considered to be those rated greater than 100 kW and small turbines are considered to be 100 kW or less.[82] Turbines produce DC or AC power, depending on the generator.[83] Small turbines usually generate DC power.[84] Generators that produce DC power need an inverter to change the power to AC for use in most equipment. See Appendix III (page 132) for information on inverters. While variable speed turbines do not produce electricity at the voltage and frequency used in most equipment, these turbines are usually equipped with features to produce

Estimating Wind Power Emissions Reductions Using EPA's Power Profiler
www.epa.gov/cleanenergy/powerprofiler.htm

Consider the 10-kW wind turbine at the Nebraska Ordnance Plant Superfund site. It is estimated to produce about 817 kWh per month. Go to the Power Profiler and enter the required information. Under "Make a Difference," select "My Emissions." Enter 817 kWh into the "Average Monthly Use" option. The Profiler estimates that about 19,000 pounds of CO_2 are released annually from producing 817 kWh of conventional energy each month. This means that the 10-kW wind turbine prevents approximately 19,000 pounds of CO_2 from being released into the atmosphere every year.

* 1 meter per second (m/s) = 2.237 miles per hour (mph)

correct voltage and constant frequency compatible with the loads.[85]

Wind power will present an advantage for locations that are not easily accessible to local utility lines.[86] The expected wind turbine lifetime is about 20–30 years.[87] See Appendix IV (page 136) for a calculation of power output.

Wind Turbine Power Curve

A wind turbine power curve shows the power output of a turbine at corresponding wind speeds. Power curves are specific to different wind turbines. A wind turbine with the power curve shown in Figure 19 may be rated for a maximum output of 500 kW. What may not be stated upfront is that wind speeds of 14-24 m/s are necessary to reach a 500 kW output. Be sure to determine the power output of a turbine for wind speeds specific to your site. Wind turbine developers can properly install a turbine that is well-suited for each site. Higher altitudes usually have faster wind speeds because winds are more turbulent closer to the ground. Though it is more expensive to install a taller tower, it is often a good investment because of the greater return in energy production.

4.3 ASSESSING WIND POWER POTENTIAL AND SIZING A WIND TURBINE

Does My Site Have Wind Power 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 at speeds of at least 10 mph (4.5 m/s) at an elevation of 33 feet (10 m) (Fig. 20). A common height for wind turbines is about 150 feet (45.7 m), where wind speeds are approximately 25 percent greater than at 30 feet.

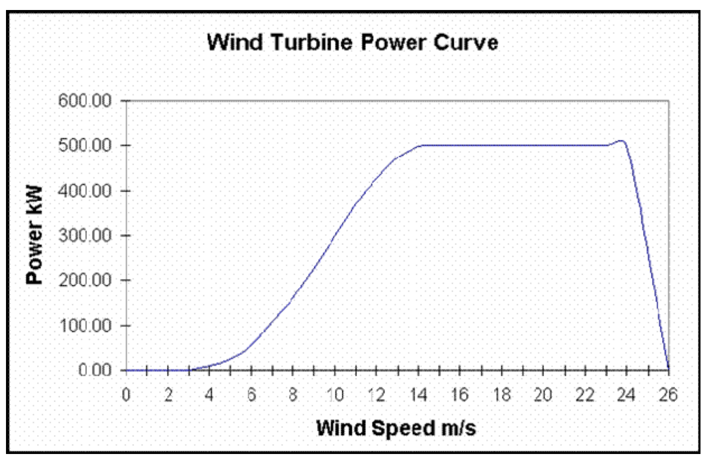

Figure 19 Sample wind Turbine Power Curve. Courtesy De Montfort University[88]

The turbine manufacturer can provide the expected annual energy output of a turbine as a function of annual average wind speed. A wind energy system, including rotor, transmission, generator, storage and other devices, will deliver approximately 10-30 percent of the energy available in the wind, depending on the manufacturer.[89] A 1.5-kW wind turbine will produce about 300 kWh per month in a location with a 14 mile-per-hour (mph) or 6.26 meters-per-second (m/s) annual average wind speed. A 10-kW turbine typically has a blade diameter of about 20-25 feet and would typically be mounted on a tower roughly 100 feet tall. If placed at a site with wind speeds of 10–15 mph, it will produce between 10,000 and 18,000 kWh per year.[90]

Wind speeds at a site can vary based on local 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. Keep in mind that, depending on the manufacturer and/or model, some turbines run more efficiently at lower wind speeds and others are more efficient at higher speeds. Consult vendors to determine which turbines will operate efficiently with wind speeds available at your site.

To view average wind speed maps, visit:

- EERE: Provides annual average wind speed maps for individual states. www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp
- NREL: Provides annual average and seasonal wind speed maps for individual states and U.S. territories. http://rredc.nrel.gov/wind/pubs/atlas/maps.html
- Bergey Windpower: Provides wind maps for individual states and U.S. territories. www.bergey.com/wind_maps.htm

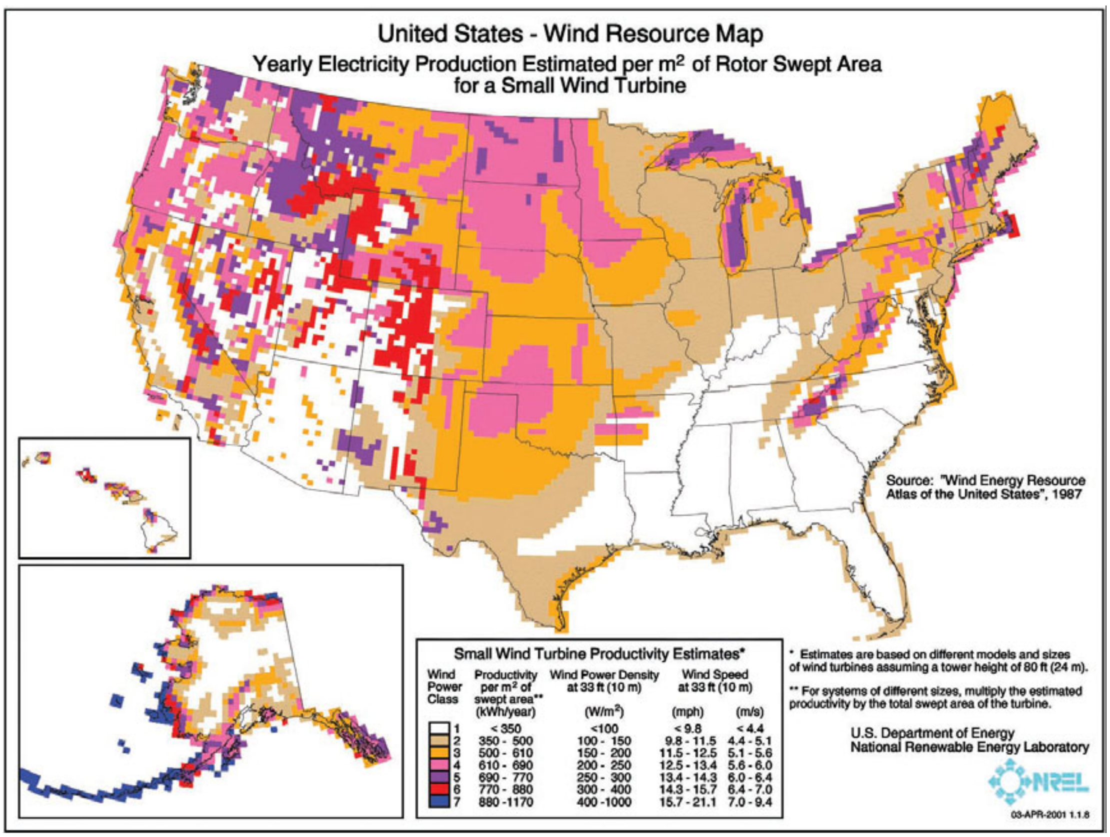

Figure 20 Wind resource map. NREL provides national wind maps and state-by-state maps.[91]

Location-specific wind speed data can be obtained using a recording anemometer, which generally costs $500-$1,500. Your local utility may provide services that lend assessment tools for renewable energy projects (See Section 10.6 page 115). The most accurate readings are taken at "hub height" (i.e., the elevation at the top of a potential wind turbine tower). This requires placing the anemometer high enough to avoid turbulence created by trees, buildings, and other obstructions.

Determining Size of Wind Power System

While solar panels are rated at an industry standard, there are no standards that apply to wind turbines. The electricity produced by a wind turbine depends on the following factors:

- Average wind speed of your site
- Length of blades (corresponds to swept area)
- Tower height
- Efficiency of system components

Use the equation in Box 4 for a rough estimate of the turbine size, in terms of rated power output (kW), needed to completely or partially provide electricity for your site.

Box 4 Estimate Turbine Rated Power Output (kW)[92]
P = E ÷ CF ÷ 8,760
P = Turbine Rated Power Output (kW) E = Site Energy Needs per Year (kWh) CF = Capacity Factor; Small Turbine Estimate ~0.25; Large Turbine Estimate ~0.30 8,760 = Hours in One Year

Box 5 Estimate Turbine Energy Production
G = P ∗ CF ∗ 8,760
G = Annual Energy Production (kWh) P = Turbine Rated Power Output (kW) CF = Capacity Factor; Small Turbine Estimate ~0.25; Large Turbine Estimate ~0.30 8,760 = Hours in One Year

Box 6 Estimate Length of Blades[93]
$AEO = 0.01328 \times D^2 \times V^3$
AEO = Annual Energy Output (kWh per year) D = Diameter of rotors (feet) V = Average wind speed (mph)

Consider a site that has an average wind speed of 7 m/s (15.6 mph) and consumes 87,000 kWh a year. Enter 87,000 kWh into the equation to find that your site would need about a 40-kW turbine to meet all the site's electricity needs, based on average electricity demand. You would need a wind turbine that outputs about 40 kW at 7 m/s wind speeds. To get a rough estimate of how much energy would be produced by this turbine at a certain speed, use the equation in Box 5. You can also use the equation in Box 6 to estimate the lengths of the blades your turbine would need to meet your site's energy demand.

These equations help to provide very rough estimates. Wind turbine manufacturers can help you more precisely size your system based a cleanup site's electricity needs and the specifics of local wind patterns.[94] They can factor in the particular wind turbine power curve, the average annual wind speed at the site, the height of the tower that you plan to use, and the frequency distribution of the wind (i.e., estimated number of hours that the wind will blow at each speed during an average year). They may also adjust this calculation for the elevation of your site.

4.4 GRID-TIED OR STAND-ALONE SYSTEMS

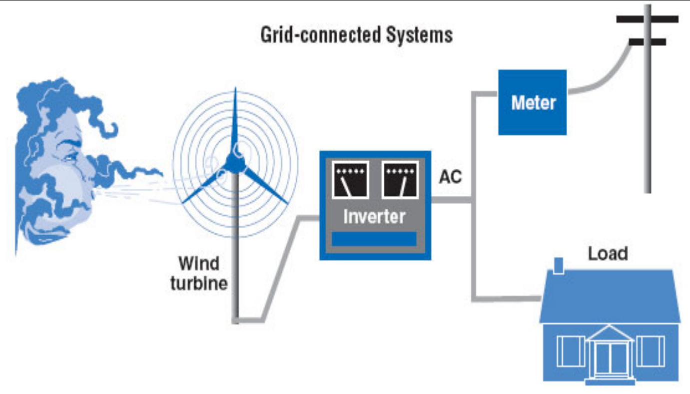

Figure 21 Grid-connected wind turbine. Image courtesy EERE[95]

Grid-tied systems have access to electricity supplied by a utility. Sites that are interconnected can receive energy both from the utility and from a local wind turbine (Fig. 21). When the turbine produces more electricity than is consumed, excess electricity is sent to the grid. Net metering programs allow grid-tied utility customers who generate electricity in excess of their consumption to credit that amount for later use.[97] When wind power is unavailable, the site can use the energy credits from the utility. Some utilities may purchase excess power generated from wind turbines. For more information on utilities that have net metering programs, see Appendix XII (page 176).

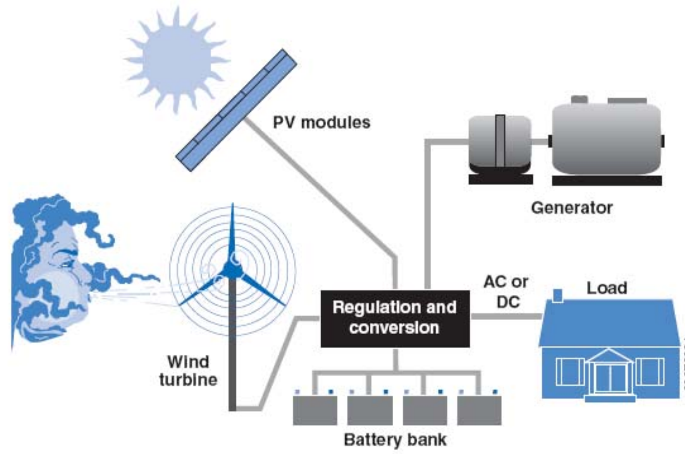

Figure 22 Stand-alone hybrid system of wind power, solar power, battery backup and clean diesel generator. Image courtesy EERE[96]

Wind power will be an even better investment if your site is not easily accessible to local utility lines.[98] The cost of extending utility lines to a remote location can cost as much as $20,000-$30,000 per quarter mile.[99] Stand-alone sites do not have access to grid-electricity. They must completely rely on wind power or a hybrid system with another renewable energy technology and/or a clean diesel generator (Fig. 22). If it is important to have a reliable, constant source of electricity, battery backup may be necessary. Battery systems can store power for use when the wind is not blowing. See Appendix III (page 130) for more information on batteries. Grid-tied systems can also consider a hybrid system to further reduce dependence on the grid.

4.5 CAPITAL COSTS, O&M, PERMITS, INSURANCE AND ENVIRONMENTAL CONCERNS

This section includes information on estimating wind turbine capital costs and payback times. It also discusses O&M costs and labor. Information on potential permit and zoning issues are also included. This section also addresses some insurance and environmental concerns.

Capital Costs

The Windfarmers Network estimates that the capital cost for a wind turbine is about $1,000 per kW of generation capacity, usually for utility-size turbines.[100] The American Wind Energy Association estimates that capital costs range from $3,000 to $5,000 per kW for smaller systems.[101] Costs may vary from project to project depending upon the size of the turbine(s), interconnection costs, permitting costs, installation and transportation costs, generator model, the type of tower and other components in your system such as batteries, inverters, and controllers. According to the American Wind Energy Association, a typical 10-kW wind turbine system will cost $25,000-$35,000. A 3-kW turbine mounted on a 60-80-ft tower costs about $15,000, including accessory components and batteries. Systems smaller than 1-kW are often used in stand-alone applications, or as part of a hybrid system with solar PV cells. A 400-watt system can be installed for $1,500.[102]

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.[103]

Well-sited small wind turbines usually have a simple payback time of 15 years, about half of their serviceable lifetimes, if federal and state incentives are applied.[105] Installing a wind turbine is usually cost effective if electricity rates are more than 10-15 cents per kWh and there are sufficient wind resources. See Section 10.3 (page 111) for economic analysis calculations and Section 10.6 (page 115) for wind power calculators.

Operation and Maintenance

Annual operating and maintenance costs for a wind turbine are estimated to be about one percent of the capital cost. 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, and insects will eventually erode the most durable blade materials, and leading edge tapes. Paint coatings, subjected to sunlight, moisture, and temperature extremes will eventually deteriorate. Also, the lubricant in the gear box, 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 (Fig. 23).[106]

Figure 23 Repairing a wind turbine. Image courtesy Argonne National Lab[104]

Permits

Permitting requirements, procedures, and fees for wind turbines vary by county. Consider zoning issues in advance since local zoning codes or covenants may not allow wind turbines. You can find out about the zoning restrictions in your area by calling the local building inspector, board of supervisors, or planning board. They should be able to tell you if you will need to obtain a building permit and provide you with a list of requirements.[107]

Costs for building permits, zoning permits, and use permits may range from $100 to $1,600. Contact your county permitting agency or planning department for information on permitting issues. Find out if small wind energy systems (under 100 kW) are addressed by your local ordinance. Review the applicable standards and restrictions. They may include minimum land size, tower height restrictions, minimum distance from the edge of the property, and maximum noise levels. The turbine must comply with the Uniform Building Code and National Electric Code. Federal Aviation Administration approval may be necessary if your site is within 20,000 feet of a runway and your tower is taller than 200 feet. Wind turbines may be subject to local restrictions if they are near coastal regions, scenic highways or other specially designated areas.[108] In many cases, a building permit for a wind turbine tower will require that the zoning board grant you a conditional use permit or a variance from the existing code.[109] Also consult neighbors before installing a turbine on your site. This is recommended and sometimes required by county planners. You may need to appear at a public hearing for a conditional use permit or variance. For grid-tied systems, contact your local utility for more information on interconnection requirements and net metering programs if applicable.[110] Consultants can also help with permitting issues.

Contact the local municipality for more information on permitting requirements. For more information on permitting issues, go to www.awea.org/smallwind/toolbox/INSTALL/building_permits.asp.

Insurance

For grid-tied systems, some utilities require small wind turbine owners to maintain liability insurance in amounts of $1 million or more. Laws or regulatory authorities in some states, including California and Nevada, prohibit utilities from imposing any insurance requirements on small wind turbines that qualify for net metering.[111]

Environmental Concerns

There has been concern over the risk that wind turbines pose to birds and bats. While wind turbines may pose a danger to wildlife if not carefully sited, fatalities from turbines are minimal compared to deaths due to buildings, windows, power lines and radio towers. Tower design changes and careful siting of the turbine will mitigate this problem.[112] Consideration of migration patterns is an important step in the process. Look into legal and environmental limitations for your site's city and county and contact your local Audubon Society.

4.6 FINDING WIND TURBINE VENDORS AND INSTALLERS

Wind power companies may provide services from designing a wind energy system to acquiring equipment to system installation. Check the following websites for databases of wind energy professionals.

- American Wind Energy Association: Searchable member directory provides list of wind energy professionals. www.awea.org, http://web.memberclicks.com/mc/page.do?orgId=awea

- General Services Administration Contracts Schedule: www.gsaelibrary.gsa.gov Search "206 3" for wind power businesses.
- California Energy Commission (CEC): California registered wind turbine retailers. www.consumerenergycenter.org/erprebate/database/index.html
- Source Guides: Worldwide renewable energy directory. www.energy.sourceguides.com

Tips to choose among wind turbine manufacturers and installers[113]

- Obtain and review the product literature from several manufacturers.
- Ask the turbine manufacturer to suggest turbines that run most efficiently at speeds comparable to wind speeds at your site.
- Ask for references of past customers with installations similar to the one you are considering.
- Ask current system owners about performance, reliability, and maintenance and repair requirements, and whether the system is meeting their expectations.
- Find out how long the warranty lasts and what it includes.
- Find out if the installer is a licensed electrician (Section 10.4 page 114).
- A credible installer will help with permitting issues.
- Consider contacting the Better Business Bureau (www.bbb.org) to check the company's integrity.

4.7 SUCCESS STORY

Nebraska Ordnance Plant Superfund Site, near Mead, NE, Region 7

The Nebraska Army Ordnance Plant operated from 1942 to 1956 as a munitions production plant. The groundwater is contaminated with VOCs and explosives and soils are contaminated with polychlorinated biphenyls. P&T technology is utilized to address groundwater cleanup. A grid-tied 10-kW wind turbine powers a single relatively low energy groundwater circulation well (GCW), operating at a flow rate of 50 gallons per minute (Fig. 24). The GCW is equipped with air strippers used to treat TCE contaminated groundwater. The site has an average wind speed of 14.3 mph (6.4 m/s). The average monthly electricity demand by principal components of the GCW is 767 kWh. On average, the wind turbine generates 817 kWh each month; the excess electricity is sent to the grid. Over the initial five months of the project, the system treated more than 4 million gallons of water and an estimated 63 kilograms (kg) of TCE were removed from groundwater. This

Figure 24 Installation of 10-kW turbine at Nebraska Ordnance Plant Dec 2003. Image courtesy EPA[114]

project was funded by the EPA's Office of Solid Waste and Emergency Response through a grant program of the Innovation Work Group, with additional support from University of Missouri-Rolla, the Kansas City District Corps of Engineers, Bergey Wind Systems, and Ohio Semitronics. Researchers estimate that the use of wind power, coupled with a well designed climate control system, may result in a present-worth energy cost savings of more than $40,000 over the 20 years of groundwater treatment anticipated at this site. Similarly-sized off-grid wind turbine systems, including installation, cost approximately $45,000. The wind turbine saved an estimated total of 17,882 pounds of CO_2 emissions over a period of 19 months.

For details, see www.clu-in.org/products/newsltrs/tnandt/view.cfm?issue=0904.cfm and www.epa.gov/oswer/docs/iwg/groundwaterFactSheet_final.pdf.

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CHAPTER 5: LANDFILL GAS-TO-ENERGY

Municipal solid waste (MSW) landfills can provide a source of energy. MSW landfills consist of everyday garbage generated from residences, businesses, and institutions. The decomposition of MSW creates landfill gas (LFG). This gas is primarily composed of CO_2 and methane (CH_4). CH_4, a GHG with high energy content, can be captured to produce electricity through the use of microturbines, boilers, or engines. As an example, Operations Industries Inc. Landfill Superfund Site in Southern California is currently powering about 80 percent of its operations buildings with landfill gas (See Section 5.7).

Chapter 5 Table of Contents

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5.5 Capital Cost and Possible Business Models
5.6 Landfill Gas Environmental and Safety Concerns and Permits
5.7 Success Stories

5.1 LANDFILL GAS-TO-ENERGY TERMINOLOGY

The following are some landfill gas-to-energy terms and definitions.

Boiler / Steam Turbine A boiler produces thermal energy from burning LFG. This heat is used in a steam turbine and generator to produce electricity. This configuration is best suited for landfills with gas production of greater than five million cubic feet per day.[115] It is the least used among LFG projects because it is more expensive than other gas power conversion technologies for the typical size of landfill projects.[116] See Appendix V (page 142).

Co-disposal landfill Landfill that may contain MSW as well as some hazardous wastes.

Collection Wells Wells strategically dug into a landfill to collect LFG. Gas collection system transports the gas to be treated and used to generate electricity or as a direct fuel.

Combustion (Gas) Turbine (CT) Energy generation equipment typically used in medium to large LFG projects, where LFG production is approximately two million cubic feet per day. This technology is competitive in larger LFG electric generation projects because of significant economies of scale. The electricity generation efficiency generally improves as size increases.[117] See Appendix V (page 139).

Compressor A device that changes the density of LFG to be compatible for use in an internal combustion engine, combustion turbine, or microturbine to generate electricity.

Condensate Liquid formed from water and/or other vapors in the LFG that condense as the gas travels through the collection pipes. Proper disposal of condensate is necessary.

Internal Combustion (IC) Engine / Reciprocating Engine Engine in which the combustion of fuel and air in a chamber produce expanding gas that can run a electricity generator. IC engines are the most widely used electricity generation technology for LFG.[118] They are typically used for generation projects greater than 800 kW.[119] See Appendix V (page 138).

Landfill gas (LFG) Gas generated when landfill waste decomposes. It is approximately 50 percent CO_2 and 50 percent CH_4.

Methane (CH_4) Highly combustible GHG that makes up about 50 percent of gas produced from a landfill. This gas can be used directly to generate heat or as a fuel to produce electricity. Methane makes up more than 90 percent of typical natural gas.

Microturbine Small combustion turbine with rated power outputs that range from 30-250 kW and can be combined with each other. They are better-suited to landfills where gas production is low (low concentrations of CH_4 and/or low flow) to economically use a larger engine and for sites with on-site energy use. Microturbine heat rates are generally 14,000-16,000 BTU per kWh. The total installed cost for a LFG microturbine project is estimated to be $4,000-$5,000 per kW for smaller systems (30 kW), decreasing to $2,000-$2,500 per kW for larger systems (200 kW and above). Operation and maintenance costs are about 1.5-2 cents per kWh.[121] The addition of a heat recovery system adds $75-$350 per kW.[122] The CA Energy Commission estimates annual maintenance costs to be 0.5-1.6 cents per kWh, which would be comparable to costs for small reciprocating engine systems.[123]

Municipal Solid Waste (MSW) Everyday garbage generated from residences and institutions.

5.2 LANDFILL GAS-TO-ENERGY TECHNOLOGY BASICS

Landfill gas is composed of about 50 percent CO_2, 50 percent CH_4, and traces of non-methane organic compounds (NMOC). In the U.S., landfills are one of the largest sources of anthropogenic (human-made) CH_4 released into the atmosphere.[124] One kilogram of CH_4 gas in the atmosphere creates 23 times the global warming effect as one kilogram of CO_2 over a 100 year period.[125] For more information on GHG

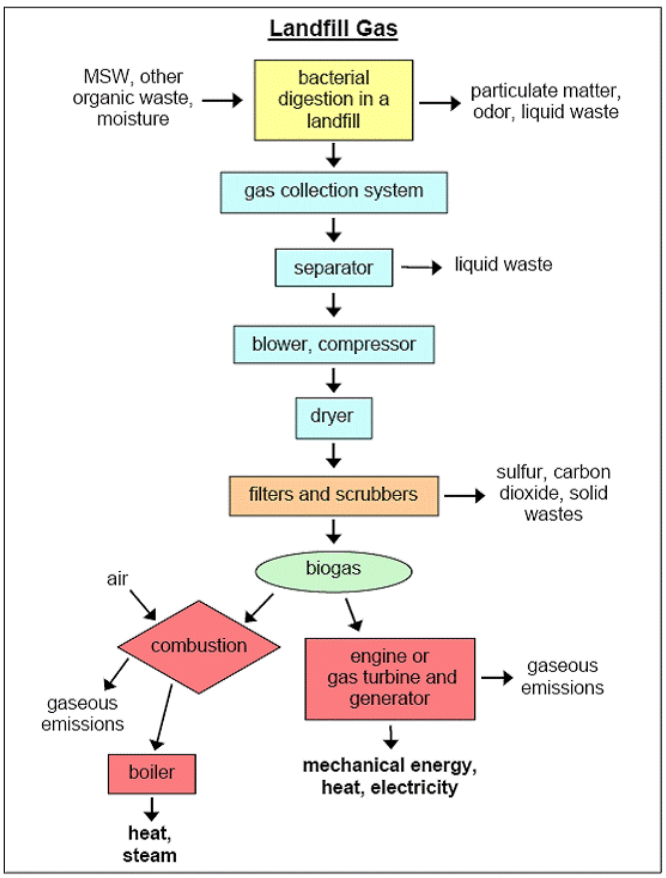

Figure 25 LFGE processes.
Image courtesy Oregon Department of Energy[120]

global warming potentials, go to www.eia.doe.gov/oiaf/1605/gwp.html. Methane 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 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 (Fig. 25). A series of wells drilled into the landfill can collect the gas and transport it through a system of pipes to be cleaned (Fig. 26) and then (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.[126] Landfill gas may also be sold as pipeline quality gas for direct use in heating applications such as for greenhouses, dryers, boilers, and many other industrial purposes.

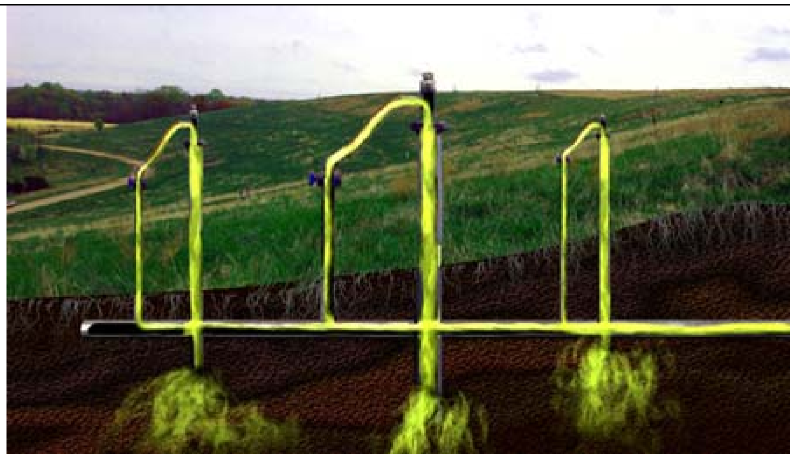

Figure 26 Landfill gas wells and collection piping. Image courtesy LMOP[127]

Co-disposal landfills usually produce less CH_4 because they are generally older and the LFG has already escaped to the atmosphere. They may also have more inert materials buried that do not produce CH_4. Co-disposal landfills tend to produce higher concentrations of NMOC and air toxics than MSW landfills and may be less suitable for renewable energy generation without engineering and waste disposal practices and controls. To help evaluate potential emissions from hazardous waste landfills, use EPA's *Guidance for Evaluating Landfill Gas Emissions From Closed or Abandoned Facilities* (www.epa.gov/nrmrl/pubs/600r05123/600r05123.pdf).

Estimating Emissions Reductions from a LFGE Project Using LMOP's LFGE Benefits Calculator
www.epa.gov/lmop/res/calc.htm

The Benefits Calculator estimates methane and CO_2 emissions reductions from a LFGE project. For example, a 3-MW LFGE project reduces about 6 tons of methane emissions per year and avoids 17 tons of CO_2 emissions due to fossil fuel energy generation per year. A project this size could power about 2,000 homes.

While burning LFG also generates CO_2, using LFG is considered to contribute a net zero effect to climate change because the gas came from recently living organisms that would have released the same amount of CO_2 from naturally decomposing.[128] However, note that all combustion devices, including LFGE systems, generate some NO_x emissions which are attributed to ground-level ozone and smog formation. Overall, the environmental benefit from landfill gas electricity generation projects is significant because of the large reductions in CH_4 emissions, hazardous air pollutants, and use of limited nonrenewable resources such as coal and oil.[129] Go to Section 10.7 (page 117) for the LFGE Benefits Calculator by EPA's Landfill Methane Outreach Program (LMOP).

5.3 ASSESSING LANDFILL GAS-TO-ENERGY PROJECT POTENTIAL AND SYSTEM COMPONENTS[130]

This section details the factors to consider when determining whether a landfill gas-to-energy system is appropriate for your site. Information on the components of a LFGE system is also included.

Assessing LFGE Project Potential

LMOP created a database of landfills in the country that have potential for LFGE projects (http://epa.gov/lmop/proj/index.htm). Arizona has 13 potential candidates, California has 40, Hawaii has eight, and Nevada has 5. LMOP can also help locate landfills within 20-25 miles of your site using their Locator Tool. Contact LMOP (www.epa.gov/lmop/contact) for assistance.

As a guide, 432,000 ft^3 of LFG is produced per day for every million tons of MSW in a landfill.[131] This is equivalent to 800 kW of power that could be generated. See Section 10.7 (page 117) to calculate LFG production. Site measurements are highly recommended, especially for co-disposal landfills, to more accurately quantify CH_4 flow rates. A flare may be installed to assess LFG flow before sizing energy recovery equipment.[132]

There are many factors to consider that effect the amount of gas produced at each landfill. Some of the most important factors are:[133]

Depth of landfill—a depth of at least 40 feet best-suits anaerobic conditions for producing LFG. However, LFGE projects have been successfully implemented in shallower landfills.

Amount of waste—a landfill with at least one million tons of MSW is optimal, although smaller ones may be applicable as well. Small landfills are good candidates if the gas will be used on-site or near by.

Type of waste—organic wastes such as paper and food scraps produce the most LFG. Landfills with a lot of construction and demolition, industrial, or hazardous wastes, such as co-disposal landfills, may not be as productive.

Age of landfill—as a landfill ages, the rate of CH_4 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 and produce LFG thrive best in moisture. An optimal site will have at least 25 inches of rainfall a year. Landfills in arid climates may have lower rates of LFG flow but are expected to produce LFG for a longer period of time.

For a LFGE project preliminary evaluation worksheet, go to Appendix V (page 137).

LFGE System Components

The following are components of a landfill gas-to-energy system.

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 gas. 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 the condensate is not removed, it can block the pipes 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, treated on-site, or discharged to the public sewer system. Most landfills with energy recovery systems have a flare for combusting excess gas and for use during equipment downtimes (Fig. 27).

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. 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. Electricity production systems typically include a series of filters to remove impurities that could damage engine components and reduce system efficiency.

3. Energy Recovery:

Figure 27 LFGE treatment/blower/flare station. Image courtesy LMOP[134]

Prime movers such as internal combustion (IC) engines, combustion turbines (CT), and boiler/steam turbines combined with generator systems can convert energy in LFG into electricity. 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 conversion technologies which may cause a permitting issue. NO_x controls can usually be installed to meet local requirements. CTs are typically used in medium to large landfill gas 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, as compared to other generator 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 less often used as a LFG conversion technology compared to IC or CT. It is applicable mainly in very large landfill gas projects, where LFG flow rates 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. Other technologies include microturbines and fuel cells. See Appendix V (pages 138-142) for details on electricity generation technologies. Use combined heat and power (CHP) applications along with these prime movers (heat engine[135]) to capture the thermal energy output which will improve energy efficiency. Go to Appendix V (page 138) for CHP resources. 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.

5.4 HOW MUCH ENERGY CAN A LANDFILL PRODUCE?[136]

Use the following equation to estimate the potential energy production from a landfill each year with more site specific information (Box 7). Keep in mind this is a rough estimate that does not account for losses in gas capture and transport and any efficiency losses from conversion to electricity.

See LMOP's *A Landfill Gas to Energy Project Development Handbook*, Section 2.2.1 "Methods for Estimating Gas Flow" (www.epa.gov/lmop/res/pdf/handbook.pdf) for more precise methods of estimating landfill gas production.

Box 7 Estimating Landfill Energy Production
G = F ∗ EC ∗ 365
G = Potential energy production from a landfill in one year (BTU per year)
F = LFG Flow per day (cfd); 1 million tons MSW ≈ 432,000 cfd LFG
EC = Energy content in LFG (BTU per cf); Estimate 500 BTU/cf
365 = Days in one year
. . .
BTU = British Thermal Unity (1 kWh = 3,414 BTU)
cfd = cubic feet per day
BTU/cf = energy content per cubic foot of gas

Consider the following example: Landfill gas typically contains about 500 BTUs per cubic foot. This can be used as a default if the BTU value of landfill gas at a specific site is not known. For a 5 million ton landfill with a gas flow of about 3 million cubic feet per day, the energy content would therefore be calculated as follows:

548 billion BTU per year = 3 million cfd x 500 BTU per cf x 365 days per year

5.5 CAPITAL COST AND POSSIBLE BUSINESS MODELS

Estimating Cost

Cost of a LFGE project varies depending on a variety of factors including size of the landfill, type of electricity generation technology, and site specific characteristics. Site preparation and installation costs vary significantly among locations though in general, electric generation equipment accounts for about 30-70 percent of the capital cost. Total capital includes the engine, auxiliary equipment, interconnections, gas compressor, construction, and engineering. Some landfills may already have a gas collection system in place.[137]

The California Energy Commission (CEC) estimated the following costs for LFGE projects in California in a report published in 2002 (Table 3).

Table 3 Estimated LFGE Project Costs[138]

	LFG Collection System	Blower / Flare Station	Reciprocating Engine	Combustion Turbine	Boiler / Steam Turbine
Construction Cost	$10,000 - $20,000 per acre of landfill	$350 - $450 per scfm*	$1,100 - $1,300 per kW (> 800 kW)	$1,000 - $1,200 per kW (> 3.5 MW)	$2,500 - $1,500 per kW (> 10 MW)
O & M	$400 - $900 per acre per year	$20 - $30 per scfm per year	1.6¢ - 2.0¢ per kWh	1.4¢ - 1.8¢ per kWh	1.0¢ - 1.4¢ per kWh

*Scfm: standard cubic feet per minute

In a 2005 draft document, the California Climate Action Team estimated total installed costs to range between $1,100 and $4,000 per kW of generating capacity.[139] Use software and documents listed in Section 10.7 (page 117) to estimate LFG production and costs for a MSW landfill gas project.

Possible Business Models

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

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

Review LMOP's *A Landfill Gas to Energy Project Development Handbook,* Section 7 "Selecting a Project Development Partner" (www.epa.gov/lmop/res/pdf/handbook.pdf) for more information. Though the target audience of this document is the landfill owner, it may provide some insight on partnering with other stakeholders. Find a list potential clean energy investors at www.nrel.gov/technologytransfer/entrepreneurs/directory.html.

5.6 LANDFILL GAS ENVIRONMENTAL AND SAFETY CONCERNS AND PERMITS[140]

This section provides information on LFGE environmental and safety concerns and potential permits required for developing a LFGE project.

Environmental and Safety Concerns

Dioxins and furans are a group of toxic chemical compounds known as persistent organic pollutants. Combustion processes, such as incinerating municipal waste, burning fuels (e.g., wood, coal, or oil), and some industrial processes, can release dioxins and furans into the atmosphere. Relative to many of these combustion processes, landfill gas combustion is less conducive to dioxin/furan formation.

Batteries, fluorescent light bulbs, electrical switches, thermometers and paints are some sources of mercury in a MSW landfill. Mercury may be present in landfill gas but combusting the gas converts the organic mercury compounds to less toxic inorganic compounds.

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 the following document by the Agency for Toxic Substances and Disease Registry: *Landfill Gas Primer: An Overview for Environmental Health Professionals* (www.atsdr.cdc.gov/HAC/landfill/html/toc.html).

LFGE Permits

LFGE projects must follow federal regulations related to both the control of LFG and air emissions from the electricity generation equipment. Emissions need to comply with the federal Clean Air Act and Resource Conservation and Recovery Act. 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

See LMOP's *A Landfill Gas to Energy Project Development Handbook,* Section 9 "Securing Project Permits and Approvals" for details (www.epa.gov/lmop/res/pdf/handbook.pdf). Contact LMOP for more information on permitting issues.

5.7 SUCCESS STORIES

Three examples of successful LFGE projects are presented below. Go to LMOP's website for more success stories (www.epa.gov/lmop/res/index.htm#4).

Operating Industries Inc.[141] (OII) Superfund Site, Monterey Park, CA, Region 9

OII is a Superfund site located in southern California. It was a 190-acre landfill that operated from 1948 to 1984. It accepted 38 million cubic yards of MSW and 330 million gallons of liquid industrial waste. Methane production at this landfill is about 2,500 ft^3 per minute. A LFGE project was constructed in 2002 (Fig. 28). The construction of the project cost $1.05 million and utility connection cost $105,000. It produces electricity from microturbines to save an estimated $400,000 annually by providing 80 percent of electricity needs for the operations and maintenance of the site.

For RPMs who are considering a LFGE project, OII project managers recommend briefing stakeholders early in the planning process, including local utilities, land use contacts, and federal, state and local environmental agencies. It is important to obtain a "power interconnection" application from the utility in the early stages of planning to sell power back to the grid. If using microturbines, ensure that the microturbine system can accept the LFG specific to your site. Research the microturbine vendor for experience and support for a LFGE project. An ideal situation would be to contract a turnkey system which provides a completely operational product upon delivery. It is also recommended to get a service contract for the microturbine system that includes details of the costs and time frame for implementation of the system.

Figure 28 LFG flares at OII. Image courtesy Chern[142]

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National Aeronautics and Space Administration (NASA)'s Goddard Space Flight Center (GSFC), Greenbelt, MD[143]

GSFC in Maryland is the first federal facility in the country to implement a LFGE project. Two of the five boilers at GSFC were modified in 2003 to run on LFG, and can use natural gas or fuel oil as backup. The LFG is supplied from the nearby county-owned Sandy Hill Landfill and fuels boilers to make steam that heats 31 GSFC buildings. The project illustrates a successful public-private partnership between Prince George's County, MD., Waste Management, Toro Energy, NASA and LMOP in pursuing the economic and environmental benefits of landfill gas energy. LMOP worked with NASA to assess the technical and economic feasibility of using gas from the Sandy Hill Landfill to fuel boilers at GSFC. This LFGE project will reduce 160,000 metric tons of CO_2 equivalents from being emitted over ten years. These emissions reductions are equivalent to taking 35,000 cars off the road per year or planting 47,000 acres of trees. NASA will save taxpayers more than $3.5 million over the next decade in fuel costs. Landfill gas provides 95 percent of all of the center's heating needs, with natural gas serving as the backup. Go to www.nasa.gov/centers/goddard/news/topstory/2003/0508landfill.html for details.

BMW, Green, South Carolina[144]

The BMW plant in Greer, South Carolina has a landfill cogeneration project. Landfill gas is transported through a 9.5-mile pipeline and provides 53 percent of the plant's energy needs by generating electricity with the use of gas turbines and direct use in heating water. The landfill is expected to be able to provide LFG for at least 20 years. For more information, go to www.bmwusfactory.com//community/environment/gastoenergy.asp.

CHAPTER 6: ANAEROBIC DIGESTION

Chapter 6 Table of Contents

6.1 Anaerobic Digester Terminology
6.2 Anaerobic Digester Technology Basics
6.2 Basic Digester Components, Types of Digesters and Assessing Anaerobic Digester Potential
6.3 Anaerobic Digester Energy Production
6.5 Capital Cost, O&M, Developers and Possible Business Models
6.6 Environmental Benefits and Concerns, Safety and Permits
6.7 Success Stories

Anaerobic digestion is the natural process of decomposing organic materials by bacteria in an oxygen-free environment. Anaerobic digestion produces biogas, which is mainly CO_2 and CH_4. It can be used to produce heat and/or electricity. Anaerobic digestion can be manipulated in a controlled environment, such as inside an anaerobic digester, where biogas can be collected and utilized.[145] Digesters may be designed as plastic or rubber covered lagoons, troughs, or as steel or concrete tanks.[146] Organic material such as manure, wastewater treatment sewage sludge, agricultural wastes or food processing wastes are appropriate feedstock for anaerobic digesters. Regular maintenance is required to restock biomass as well as dispose of digester byproducts, which may be used as fertilizers. Cleanup sites that have biomass sources nearby may consider using an anaerobic digester to generate electricity and gas.

6.1 ANAEROBIC DIGESTER TERMINOLOGY[147]

The following are some anaerobic digester terms and definitions.

Anaerobic Absence of oxygen.

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

Biogas The gas produced from decomposition of organic matter in anaerobic conditions consisting of 60-80 percent CH_4, 30-40 percent CO_2, and other trace gases such as hydrogen sulfide, ammonia and H_2.

Effluent Organic liquid and solid material leaving a digester.

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

Influent, or Feedstock Liquid and solid material fed to the digester.

Methane (CH_4) A combustible gas produced by anaerobic digestion and also the principle component of natural gas.

Mesophilic Range Temperature range between 95°F and 105°F in which certain methane-producing microbes thrive.

Thermophilic Range Temperature range between 125°F and 135°F where certain methane-producing bacteria are most active. In digesters, the greatest pathogen destruction occurs in this temperature range.

Slurry The mixture of biomass and water processed in the digester.

6.2 ANAEROBIC DIGESTER TECHNOLOGY BASICS

Anaerobic digestion is the natural process of decomposing organic materials by bacteria in an oxygen-free environment. One of the products of anaerobic digestion is biogas, which consists of 60-80 percent CH_4, 30-40 percent CO_2, and trace amounts of other gases. It typically has an energy value of about 600-800 BTU/ft^3.[149] This natural process can be manipulated in a controlled environment, such as in an anaerobic digester, where the biogas can be collected and used for heating and/or electricity production (Fig. 29).[150]

Figure 29 Plug-flow digester. Image courtesy Penn State University[148]

Organic material such as manure, wastewater treatment sewage sludge, agricultural wastes or food processing wastes are used in anaerobic digesters to produce biogas. Cleanup sites that have these sources nearby may consider using an anaerobic digester to generate electricity. Digesters are designed as plastic or rubber covered lagoons, troughs, or as steel or concrete tanks.[151] Carefully controlled nutrient feed, moisture, temperature, and pH in the digester make a habitable environment for the anaerobic bacteria, which are naturally occurring in manure (Fig. 30).

Digesters work best with biomass that is greater than 85 percent moisture by mass. Digesters operate at two ideal temperature ranges: mesophilic temperatures (95˚F-105˚F) which best host mesophile bacteria, and thermophilic temperatures (125˚F-135˚F) which best host thermophile bacteria.[152] See Appendix VI (page 145) for more information on digester biology. Thermophilic conditions decrease the hydraulic retention time, reducing the size of the digester needed compared to digesters operating under mesophilic temperatures.[153] However, thermophilic bacteria are also much more sensitive to changes in their environment, so digester conditions must be closely monitored and maintained. Digesters operating at thermophilic temperatures also need more energy to heat them. Excess heat from operating the electricity generators or direct combustion of the produced biogas may be able to provide enough thermal output to heat the digester. There is little change in the volume of the organic matter after it goes through the digester. The digested solids and liquids can be used as high-quality fertilizer (See Appendix VI page 146). The effluent can be spread on fields as a liquid fertilizer or liquids and solids can be separated to be sold individually.

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. Because anaerobic digestion reduces ammonia losses, digested manure contain more valuable nitrogen for crop production. The nutrient content of digested manure is the same as in raw manure. Some liquid content can be re-fed into the digester in the case that the moisture content needs to be increased.

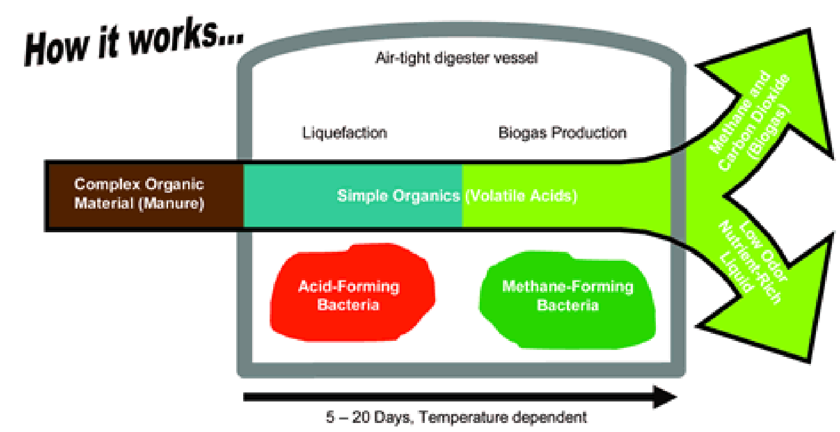


Figure 30 Bacterial processes within an anaerobic digester.
Image courtesy Penn State University[154]

Benefits of an anaerobic digester include:

- Green energy production.
- In the case of manure digesters, reduced odor compared to conventionally stored liquid manure, reducing potential nuisance complaints.
- Digested material can be pumped long distances for use as fertilizer.
- Reduction of pathogens and weed seeds in digested material.
- Reduced fly propagation.
- Use of digested material as fertilizer, potting soil, or mulch.

6.3 BASIC DIGESTER COMPONENTS, TYPES OF DIGESTERS AND ASSESSING ANAEROBIC DIGESTER POTENTIAL

There are many types of digesters but all share similar components. This section discusses the various components of a digester system and various anaerobic digester types. Information on assessing the potential of a digester project for a site is also provided.

Basic Components of All Digesters[155]

The following are descriptions of the components of an anaerobic digester biogas recovery system.

The digester system components include (Fig. 31):

Nutrient Source Organic material including animal manure, wastewater treatment sewage sludge, food waste, food processing wastes. It is possible to combine different sources of organic matter to feed into the digester.

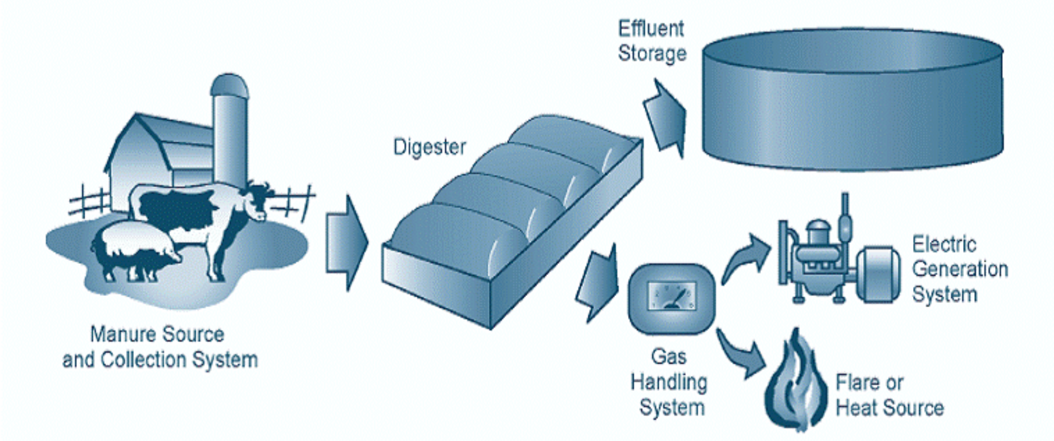


Figure 31 Components of an digester biogas recovery system. Image courtesy AgStar[156]

Transport System Most digesters are constructed on-site near the nutrient source. The organic matter must be collected and fed into the digester.

Pre-treatment Tank A pre-treatment tank is sometimes recommended. This tank is used to preheat the influent as well as 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.

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, boilers/steam engines, or microturbines and generators can produce electricity from the biogas. See Appendix V (pages 138-142). The waste heat can be captured and recycled to heat the digester.

Flare or Heat Source Excess CH_4 is flared. Methane can also be used directly for heating the digester or other processes.

Effluent Storage Digested material 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.

Types of Digesters

Choosing the most suitable digester depends on the moisture content of the influent and, in the case for covered lagoon, climate at the site. The digesters detailed below are conventional designs including complete-mix, plug-flow, and covered lagoon digesters. This section also includes information on where a digester project may be applicable.

Complete-Mix Digester

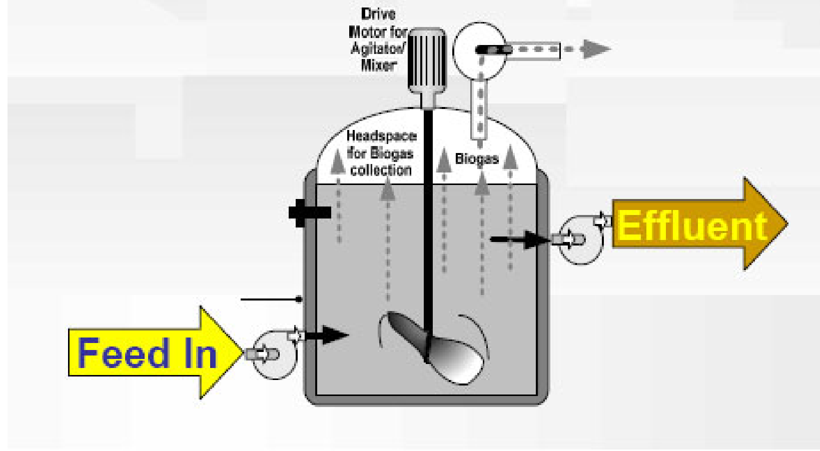
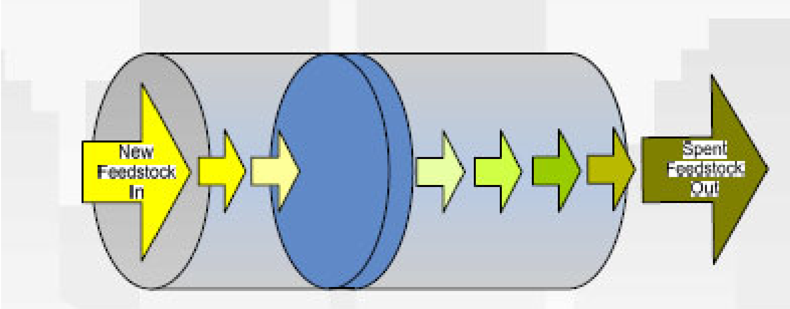


Figure 32 Schematic of a complete-mix digester.
Image courtesy Ohio State University [157]

The complete-mix digester is a vertical concrete or steel circular container that can be installed above or below ground (Fig. 32). It can handle organic wastes with total solid concentration of 3-10 percent, 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 HRT of 10-20 days. A mixer keeps the solids in suspension. For manure feedstock, cost estimates range from $200-$400 per 1,000 pounds of animal mass that contribute to the digester influent.[158]

Plug-Flow Digester



33 Schematic of a plug-flow digester.
Image courtesy Ohio State University[159]

The basic plug-flow digester design is a rectangular trough, often built below ground level, with an impermeable, flexible cover (Fig. 29 page 48). Organic material is added to one end of the trough and decomposes as it moves through the digester. Each day a new "plug" of organic waste is added, pushing the feedstock down the trough (Fig. 33). Plug-flow digesters are suitable for biomass with a solids concentration of 11-13 percent and have a HRT of about 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. For manure feedstock, cost estimates range from $200-$400 per 1,000 pounds of animal mass that contribute to the digester influent.[160] n

Covered Lagoon Digesters

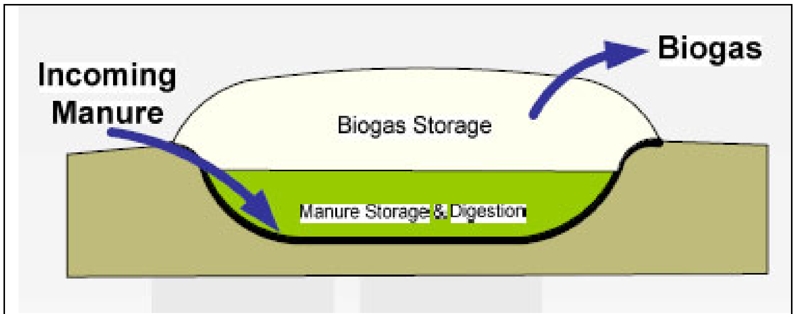


Figure 34 Covered lagoon digester. Image courtesy Ohio State University[161]

A covered lagoon digester is a lagoon fitted with a floating, impermeable cover that collects biogas as it is released from the organic wastes (Fig. 34). An anaerobic lagoon is best suited for liquid organic wastes with a total solid concentration of 0.5-3 percent. Covered lagoon digesters are generally not externally 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 mentioned here. For manure feedstocks, cost estimates range from $150-$400 per 1,000 pounds of live animal mass that contribute to the digester influent.[162]

Other digester designs include advanced integrated pond systems, up-flow solids reactors, fixed-film (Fig. 35), temperature-phased, and anaerobic filter reactors.[163]

Siting Anaerobic Digesters

A suitable location for anaerobic digester energy project should be close to an organic waste source. It may be possible to collect organic wastes from a community, such as local farms and food processing facilities that have a need to dispose biomass. To consider a manure digester project for energy production, the manure influent supply should generally 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) from which manure is collected regularly.[165] The influent source should be available year-round for a constant supply of biogas and energy production. 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. Manure feedstock should 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 long-term maintenance. Consider uses for the digested material, both liquid and solid components, such as for fertilizers. See Appendix VI (page 143) for a preliminary evaluation checklist for manure feedstock.

Figure 35 Fixed-film digester. Image courtesy University of Florida[164]

6.4 ANAEROBIC DIGESTER ENERGY PRODUCTION

Producing biogas is just one step to harnessing energy from organic wastes. Once the gas has been collected, engines or boilers coupled with generators are utilized to convert the energy contained in the biogas to heat and/or electricity to be used on the cleanup site. The term “prime mover” is often used to refer to heat engines which generate mechanical energy that can drive electricity generation equipment. See Appendix V (pages 138-142) for more details.

Energy Generation Options

Internal Combustion Engine / Reciprocating Engine An internal combustion engine is the most commonly used technology for utilizing biogas. Natural gas or propane engines can be modified to burn biogas. In general, a biogas-fueled engine generator is 18-25 percent efficient at converting energy in biogas to electricity.[166] Optimize efficiency by using the co-generated heat energy for space heating, water heating, and/or heating the digester. When a reciprocating engine is used, the biogas must have condensate and particulates removed. [167]

Boiler / Steam Turbine A boiler can produce thermal energy from burning biogas. The heat is used in a steam turbine to generate electricity. This configuration is best suited for gas production that can generate 8-9 MW, which is very large for a digester project.[168] At smaller scales, it is generally more expensive than other gas power conversion technologies.

Combustion (Gas) Turbine Combustion turbines (CTs) are typically used in medium to large biogas projects rated from 3-4 MW. 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 any particles removed and then must be compressed in order to be utilized in a gas turbine combustion chamber.

Microturbines Microturbines range in power rating from 30-250 kW and can be combined with each other. They are better-suited for digester projects for which low CH_4 concentrations or low flow rates prohibit the applicability of larger engines. Microturbines cost from $700 per kW to $1,100 per kW of generation capacity. The addition of a heat recovery system, which captures the otherwise wasted heat, adds between $75 and $350 per kW.[169] Microturbines require very clean biogas fuel, increasing the cost for biogas cleanup.

Potential Energy Production

The amount of energy a digester can produce depends upon the type of feedstock, type of digester, environment inside the digester, loading rate, and type of energy recovery technology. Table 4 includes electricity production rates compiled by the California Energy Commission (CEC) which provides a general estimate of the energy production potential of different manure feedstocks. Other influent sources including cheese whey (about twice as much biogas production as manure), animal and vegetable fats and oils (about 20 times as much biogas production as manure), crop and green wastes, and food processing waste, yield even greater amounts of biogas. Different feedstocks can be combined to increase biogas production.[170] If you are considering dairy manure as a feedstock for a digester, use the CEC Dairy Power Production Program’s worksheet for estimating energy production (Appendix VI page 144). The heat generated from the engine or turbine generator is also a useful resource that can be harnessed instead of being released as waste heat. See Appendix V (page 138) for combined heat and power application information.

Table 4 Energy Potential of Various Animal Manures[171]

Anaerobic Digestion Feedstock	Volatile Solids per animal per day (lbs/day)	Energy Potential (kWh/animal/day)
Dairy Cows	6.2	1.24
Swine	1.64	0.328
Layer Poultry	0.048	0.0096
Broiler Poultry	0.034	0.0068
Turkey	0.091	0.0182
Sheep and Lamb	0.92	0.184

6.5 CAPITAL COST, O&M, DEVELOPERS AND POSSIBLE BUSINESS MODELS

This section includes information on estimating the capital cost for an anaerobic digester, associated operations and maintenance, resources to find digester developers and possible business models for an anaerobic digester project.

Estimating Cost

For a manure digester, the joint EPA, USDA, and DOE AgStar Program estimates the installed capital cost of a covered lagoon, complete mix, and plug flow digester to range between $200 and $450 per 1,000 pounds of animal mass that provide feedstock to the digester (Table 5). AgStar estimates a 3-7 year payback period when energy recovery is employed.[172] Contact digester developers for cost estimates for other feedstocks.

Table 5 Cost Estimates for Various Manure Management Options
(per 1,000 pounds of animal mass that contribute feedstock)[*173]

Aerated lagoons with open storage ponds (for comparison)[♣]	$200-$450
Covered lagoon digesters with open storage ponds	$150-$400
Heated digesters (e.g., complete mix and plug flow) with open storage tanks	$200-$400
Separate treatment lagoons and storage ponds (2-cell systems)	$200-$400
Combined treatment lagoons and storage ponds	$200-$400
Storage ponds and tanks	$50-$500

[*] Cost estimates are from a 2002 publication. Cost ranges do not include annual operation and maintenance costs.
[♣] Aerated lagoon energy requirements add an additional $35-50 per 1,000 live animal lbs/year.

Download FarmWare from www.epa.gov/agstar/resources/handbook.html to get preliminary feasibility and economic analyses of manure digesters.

Operations and Maintenance

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 one hour per day. Oil in the engine may need changing every few months. Digesters may need to be cleaned out after several years of operation.

Finding a Developer

The following links provide listings of anaerobic digester consultants, developers, and equipment suppliers. Select businesses based on their previous biogas project experience, successful project track record, and in-house resources such as engineering, financing, operations and experience with environmental permitting and community issues.[174]

- The AgSTAR Industry Directory: Listing of consultants, project developers, energy services, equipment manufacturers and distributors, and commodity organizations. www.epa.gov/agstar/tech/consultants.html
- The California Integrated Waste Management Board: Listing of anaerobic digester vendors. www.ciwmb.ca.gov/Organics/Conversion/Vendors
- Penn State Department of Agriculture and Biological Engineering: Listing of digester consultants, designers, and vendors. www.biogas.psu.edu/listdigandequip.html

Partners and Possible Business Models

Purchasing and operating an anaerobic digester may involve many different parties. Consider the following:

- Appropriate level of involvement with the local utility if the digester is expected 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 feedstock provider(s).
- Which party will own, operate and manage the digester.
- County, community, union organization involvement.

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.

Find a list potential clean energy investors at www.nrel.gov/technologytransfer/entrepreneurs/directory.html.

6.6 ENVIRONMENTAL BENEFITS AND CONCERNS, SAFETY AND PERMITS

This section includes information on the environmental benefits of a digester project, mainly emission reductions. It also highlights some environmental concerns and safety issues. Information on possible permit requirements is also included.

Emissions Reductions[175]

Use AgStar's *A Protocol for Quantifying and Reporting the Performance of Anaerobic Digestion Systems for Livestock Manures* (www.epa.gov/agstar/pdf/protocol.pdf) to estimate GHG reductions from the use of a manure digester. Utilizing anaerobic digesters, rather than conventional manure management practices, can reduce CH_4 and nitrous oxide (N_2O) emissions, two highly potent GHGs. CO_2 emissions from livestock are not estimated because annual net CO_2 emissions are assumed to be zero – the CO_2 photosynthesized by plants is returned to the atmosphere as respired CO_2. A portion of the carbon is emitted as CH_4 and for this reason CH_4 requires separate consideration.[176] Methane emission reductions should not be based on CH_4 production from the digester. Methane generated from conventional manure practices often differ from the amount produced in an anaerobic digester. To estimate baseline emissions, calculate the CH_4 emissions from a conventional manure management method, or the method that would have been in place if a digester was not installed. The methodology described in the EPA Climate Leaders "Draft Manure Offset Protocol" is found at www.epa.gov/stateply/documents/resources/ClimateLeaders_DraftManureOffsetProtocol.pdf.

Estimating Digester Emissions Reductions with EPA's Power Profiler
www.epa.gov/cleanenergy/powerprofiler.htm

Consider Gordondale Farms (Section 6.7) which has a digester fueled with manure from their 860 cows. Their digester system produces about one million kWh per year. Go to the Power Profiler and enter the required information. Under "Make a Difference," select "My Emissions." Enter 83,000 kWh into the "Average Monthly Use" option. The Profiler estimates that about two million pounds of CO_2 are released from producing one million kWh of conventional electricity a year. This means that use of the digester gas prevents an estimated two million pounds of CO_2 from being released into the atmosphere every year.

While CO_2 emissions from manure management are usually not counted towards a carbon footprint as mentioned above, there is carbon savings if the biogas is used to produce electricity. Instead of using fossil fuel electricity, carbon is offset by using renewable biogas.

FarmWare may be used to help estimate the emissions from anaerobic lagoons with secondary storage and combined storage and treatment lagoons (www.epa.gov/agstar/resources/handbook.html).

Environmental and Safety 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.

Sulfur oxides (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.

Since biogas is flammable and displaces breathable oxygen within the space it occupies, it is potentially dangerous and it is necessary to take safety precautions including, but not limited to, installing and monitoring gas detectors, eliminating ignition sources, posting warning signs and never entering an empty digester without extensive venting and a confined space entry permit in accordance with Occupational Safety and Health Administration regulations. 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 on digester safety.

Permits

It is essential to garner appropriate permits early in the digester design 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
- Storm-water management
- Air

See *AgStar Handbook,* Chapter 8 "Permitting and Other Regulatory Issues" for more details (www.epa.gov/agstar/pdf/handbook/chapter8.pdf).

6.7 SUCCESS STORIES

Dairy Manure: Gordondale Farms, Nelsonville, WI[177]

Gordondale Farms is a 3,200 acre dairy farm located in Nelsonville, Wisconsin with a milking herd of about 860 Holstein-Friesian cows. They use a two-stage modified plug-flow mesophilic digester with vertical gas mixing. The captured biogas is used to fuel a modified 150-kW engine generator set. While the farm owns the digester, the local utility, Alliant Energy, owns and operates the electricity generation equipment and owns the electricity generated. Alliant Energy pays Gordondale Farms at the rate of $0.015 per kWh delivered and all electricity used by Gordondale Farms is purchased from the utility at retail rates. Biogas production was estimated to be 93,501 ft^3 per day with 860 cows. For each 1,000 ft^3 of biogas utilized, about 30 kWh are generated. Liquid and solid residuals are separated. Liquids are used as fertilizer and the solid portion is used on-site and sold as bedding for dairy farms. Cost for design, materials, and construction was estimated to total $650,000 (completed March 2002). The owners of this system partially constructed the digester themselves, reducing the capital cost. The installed cost of the engine-generator set was $198,000. The engine-generator itself and interconnection fees totaled $160,000 while the remaining $38,000 was the cost of generator installation, including labor and materials.

Dairy Manure: California Dairy Power Production Program, various locations, CA

The Dairy Power Production Program was funded by the CEC and contracted to the Western United Resource Development Corporation (WURD). The purpose of the Dairy Power Production Program was to encourage the development of biological-based anaerobic digestion and gasification electricity generation projects on California dairies. The overall goal of this effort was to develop commercially proven biogas electricity systems that can help California dairies offset the purchase of electricity, and may provide environmental benefits by potentially reducing air and ground water pollutants associated with storage and treatment of livestock wastes. Total funds allocated for this project was $9,640,000.[178] All funds have been granted and future funding for this program is uncertain. The following is a summary of many of the projects that were completed through this program (Table 6). From the data below, a covered lagoon and generator set costs about $3,500 per kW and plug-flow digesters and generator set costs an average of about $3,000 per kW of generating capacity.

Table 6 California Dairy Power Production Program Digester Projects[179]

Dairy Name	Cows	Type of System	kW	Total Cost
Hilarides Dairy	6,000 heifers	Covered Lagoon	250	$1,500,000
Gallo Cattle Company	5081	Covered Lagoon	300	$1,289520
Blakes Landing Dairy	237	Covered Lagoon	75	$135,800
Castelanelli Bros. Dairy	1600	Covered Lagoon	160	$772,925
Koetsier Dairy	1500	Plug Flow	260	$381,850
Van Ommering Dairy	600	Plug Flow	130	$489,284
Meadowbrook Dairy	1900	Plug Flow	160	$524,898
CA Polytechnic State University Dairy	175	Covered Lagoon	30	$75,000
Lourenco Dairy	1258	Covered Lagoon	150	$229,557
Inland Empire Utilities Agency	4700	Plug Flow	563	$1,546,350
Eden-Vale Dairy	770	Plug Flow	150	$661,923

See the CEC (www.energy.ca.gov/pier/renewable/biomass/anaerobic_digestion/projects.html) and WURD (www.wurdco.com/) websites for more information on the CA Dairy Power Production Program.

Food Processing: Valley Fig Growers Biogas Project, Fresno, CA[180]

Valley Fig Growers is a grower-owned marketing cooperative with 35 growers. They installed an anaerobic digester at their processing facilities in Fresno, California to help mitigate their wastewater issues and to produce electricity. The digester and microturbine system began operations in May 2005.

The Fig Growers installed a covered lagoon and a 70-kW Ingersoll Rand microturbine. The lagoon is 26,500 ft^2 (0.6 acres) with a 1.8 million gallon capacity. The retention time is 45 days with gas production of 2,000–2,500 ft^3 per hour. In 2002, the CEC Public Interest Energy Research (PIER) Program awarded the Valley Fig Growers $476,000. Biogas from the digested fig processing wastewater is used to generate electricity and heat. The Fig Growers use a total of 40,000 gallons of fresh water daily for processing, seven days a week. With high levels of organic matter in their wastewater, the Valley Fig Growers were charged $100,000 a year to discharge their wastewater into city sewers.

Benefits

The digester reduced biochemical oxygen demand and suspended solids by 70-80 percent. The estimated cost savings from this reduction is $115,000 per year. They save $90,000 each year from reduced wastewater discharge fees. Electricity produced from the digester saves the Fig Growers $25,000 each year in energy costs.

Costs[181]

The digester system cost a total of about $1.1 million. See the breakdown of the costs below.

<u>Digester</u>	
Engineering and project management	$478,000
Earthwork	$210,000
Lagoon liner and cover	$219,000
Digester and aeration	$229,000
Gas collection, heating	$270,000
<u>Microturbine</u>	
70-kW microturbine	$163,000
Engineering and commissioning	$13,000
Freight and sales tax	$8,000
3-year maintenance contract	$38,000
Utility rebate	($70,000)
<u>Other Costs</u>	
Road surface, fencing, landscaping	$65,000
Interest	$65,000
Total	$1,676,000
<u>PIER grant and utility rebate</u>	($546,000)
<u>Net total cost</u>	$1,142,000

Permitting[182]

- San Joaquin Valley Air Pollution Control District—permit to operate, emissions requirements
- City of Fresno Building Permit—city inspectors may not be familiar with microturbines and may be unsure of the inspection process for microturbines
- CA Regional Water Quality Control Board—submit groundwater monitoring network plan and waste discharge permit
- CA State Water Resources Board—general permit to discharge storm water

Valley Fig Recommendations[183]

- Test biogas quality to ensure compatibility with engine/turbine.
- Ensure that all correct O rings are used.
- Ensure that gas line regulators are properly installed to prevent potential fires.
- Negotiate equipment maintenance in the early stages of contracting.
- For bacteria to start producing biogas quicker during early stages of digester use, find similar digester material from other digesters as seed material.
- Contact local utilities early to resolve any interconnection issues and net metering rules.
- Plan for alternative uses of excess biogas.
- Investigate the underground characteristics of the planned digester site before construction.
- Be warned that if the project receives a state grant of more than $1,000, prevailing wages must be paid, increasing construction costs. Be sure contractors are aware of these grants.
- Utilize heat produced by the microturbine to heat the digester.
- Look for simple solutions to minimize the complexity of operations and maintenance. Budget for automation only when needed.
- Address water quality, air quality and other permitting issues early in design phase and negotiate annual fees ahead of time.
- Find a project manager with experience in both construction and operation of anaerobic digesters.

CHAPTER 7: BIOMASS GASIFICATION

Chapter 7 Table of Contents

7.1 Gasifier Terminology
7.2 Gasifier Technology Basics
7.3 Gasifier System and Energy Generation
7.4 Assessing Biomass Gasifier Project Potential
7.5 Emissions Reductions, Capital Cost, Permits, Involved Parties and Partnerships
7.6 Success Story

Biomass such as manure, crop residue, and other agricultural wastes may be gasified to produce electricity. Instead of relying on biological processes as in anaerobic digestion, gasification is the process of heating material in a chamber at carefully controlled temperature, pressure, and moisture levels to produce high energy syngas. Syngas consists of CO and H_2, which can be used to generate electricity. Cleanup sites that have access to biomass may consider gasification to provide power. Gasifier projects require high capital costs as well as regular maintenance to restock biomass and dispose byproducts. While biomass gasification is not strongly established, many companies are emerging to develop this technology.

7.1 GASIFIER TERMINOLOGY[185]

The following are some gasifier terms and definitions.

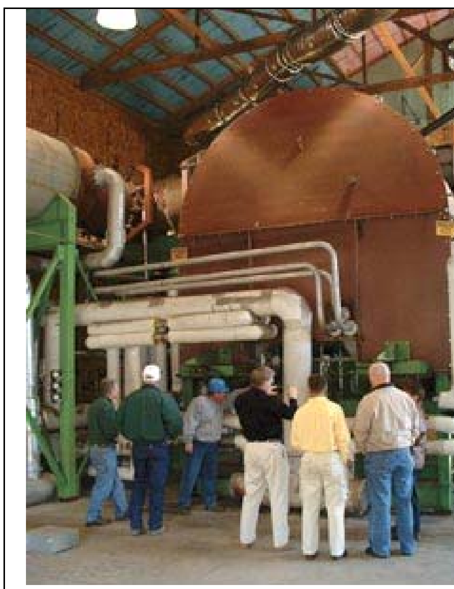


Figure 36 Coaltec Energy USA's small-scale gasifier. Image courtesy Coal Research Center[184]

Char A combustible residue of carbonaceous feedstock.

Feedstock A raw material used in the manufacture of a product. In the case of gasification, biomass feedstock could include agricultural residues or manure.

Gasification Conversion of low-value carboniferous feedstocks to higher-value gaseous fuels.

Gasifier Main component of a gasification system, which converts a solid or liquid into a gas by means of heat and pressure in the presence of low levels of oxygen.

Methane (CH_4) The primary constituent of natural gas.

Oxidation A chemical reaction in which oxygen is added to an element or compound.

Slurry A liquid mixture of water and an insoluble solid, such as coal.

Syngas A gaseous fuel produced from gasification composed of CO and H_2 gas.

Town gas Coal-based syngas provided by municipalities for heating and lighting, primarily in the 19th century.

Water - gas shift reaction An inorganic chemical reaction in which water and CO react to form CO_2 and H_2 (water splitting). CO + Water (H_2O) + catalyst + heat = CO_2 + H_2.

7.2 GASIFIER TECHNOLOGY BASICS

Gasifiers extract energy from biomass to generate electricity (Fig. 36). Although coal can be gasified to produce energy, only when biomass is used is it considered renewable energy. Gasification uses heat, pressure, and steam to convert carboniferous matter (i.e., biomass and coal) into synthesis gas (Fig. 37). Synthesis gas or "syngas" is composed primarily of CO and H_2.[188] CO and H_2 are colorless, odorless, and highly flammable gases that can be used to generate electricity. Gasification is not the same as combustion. Gasification utilizes only about one-third of the oxygen needed for efficient combustion. The syngas that is produced from gasification can be used to produce steam or to fuel gas turbines.[189] Gasification can be applied to a wide variety of organic feedstocks including waste material from agriculture, forestry operations, food processing, and pulp and paper mills. (Fig. 38).[190] Cleanup sites that have these sources nearby may consider using gasification to generate electricity. See Appendix VII (page 147) for more information on the gasification process.

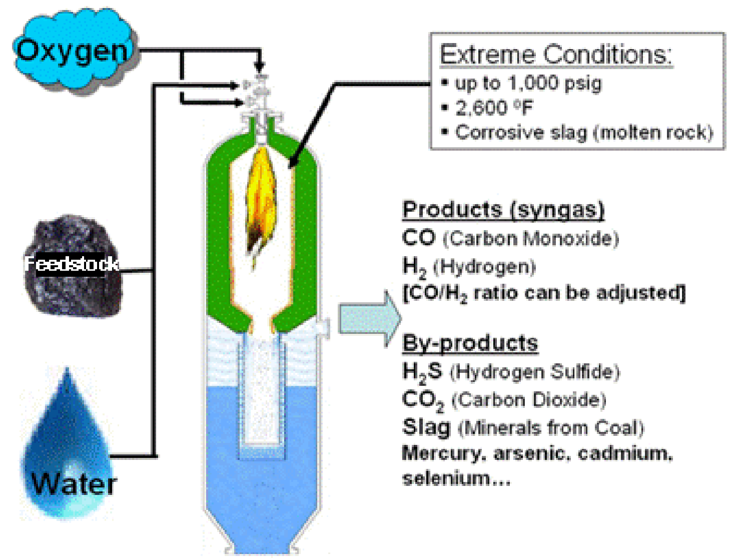


Figure 37 Gasification inputs and outputs. Adapted from image courtesy NETL[186]

Figure 38 Gasifier fueled with poultry litter in West Virginia. Image courtesy Coaltec Energy USA[187]

While coal gasifier technology had been used in the early 1800's to produce syngas for lighting and cooking, applications for biomass gasification for the purpose of full scale energy generation have not been fully established. Gasification is a complex technology and feasibility and applicability depend on many site-specific and feedstock variables. Some challenges with biomass gasification compared to coal gasification include its heterogeneous properties, low bulk density, and fibrous nature of herbaceous feedstock. These differences require specialized design and operation as compared to coal gasification. [191]

7.3 GASIFIER SYSTEM AND ENERGY GENERATION

This section includes information on the components of a gasifier system and details electricity generation equipment that can utilize syngas.

Gasifier System

The following image depicts the different components of a gasifier system (Fig. 39):

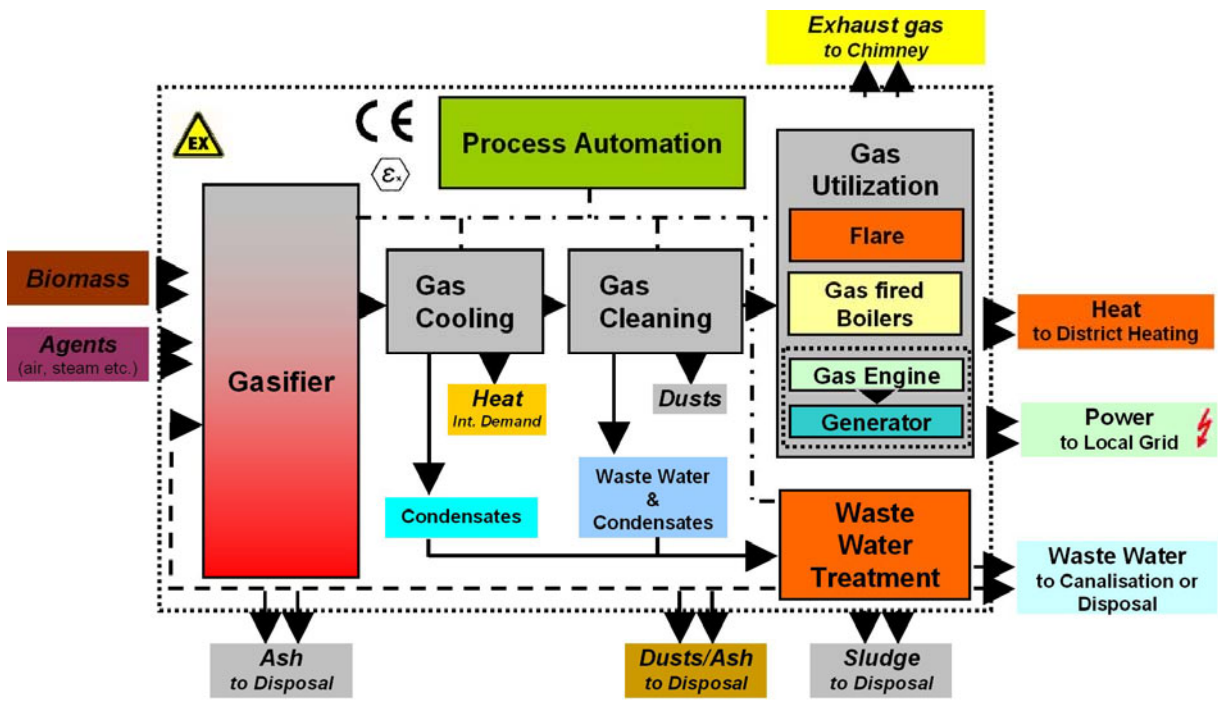


Figure 39 Biomass Combined Heat and Power Gasification Plant. Image courtesy "Gasification Guide"[192]

Energy Generation[193]

Different sources of feedstock have varied energy content. Lab tests are necessary to determine the potential energy content in a fuel. Discuss with your gasifier consultant the amount of energy a gasifier is expected to produce with the type and amount of biomass available at your site.

Combustion (gas) turbines and steam turbine-generators can use syngas and waste heat to generate electricity (see Appendix V pages 139-142). To produce electricity, the syngas leaves the gasifier and first must be cleansed of impurities such as alkalis, ammonia, chlorides, sulfides and particulates with the use of scrubbers. The syngas is then ignited to drive a combustion turbine and create electrical power through the use of a generator. Waste heat from the turbine can be used to boil water and create steam to drive a steam turbine with its own generator set. This combined heat and power operation increases energy efficiency by 33 percent compared with using a combustion turbine alone (see Appendix V page 138).

Alternatively, the CO and water in syngas may be converted to H_2 and CO_2 via a water-gas shift reaction. Hydrogen is a very clean burning fuel that can be used in fuel cells. Water may be added to the syngas prior to the water-gas shift reaction to increase the production of H_2. The syngas may also be turned into a clean burning diesel-like fuel using the Fischer-Tropsch process (a catalyzed chemical reaction).[194] Go to www.eere.energy.gov/afdc/pdfs/epa_fischer.pdf for an EPA factsheet on Fischer-Tropsch fuels.

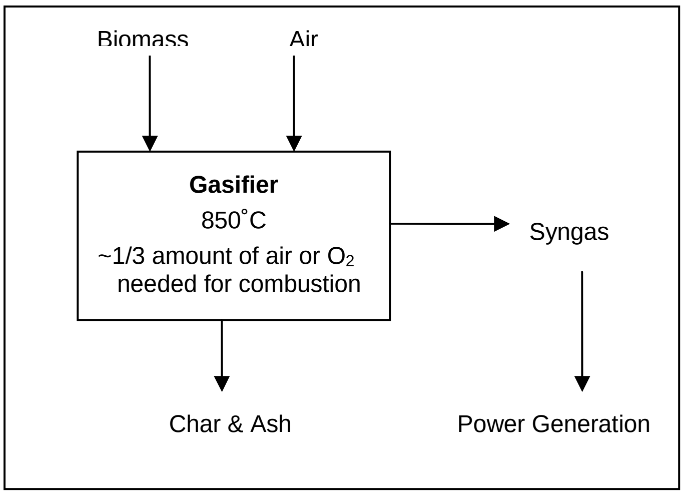


Figure 40 Small modular gasifier process (5 kW – 5 MW). Adapted from image courtesy EERE[195]

7.4 ASSESSING BIOMASS GASIFIER PROJECT POTENTIAL

Gasification can be done on a large utility scale or a smaller scale. Cleanup sites most likely can be powered with small scale gasification systems which are rated between 5 kW and 5 MW (Fig. 40).[196] If there is a large source of biomass in the surrounding area, you may consider a larger facility to supply electricity to remediation equipment and to the utility grid. See Appendix XII (page 176) for net metering programs available in Region 9 states. There should be a source of biomass nearby and transportation costs should be taken into consideration when planning a gasifier.

After establishing that there is a potential source of biomass in the cleanup site area, you may need to consult the owner of the biomass resource for a potential partnership. You may then want to contact a biomass energy consultant for further assessment (see Section 10.9 page 119). Samples of biomass should be analyzed for energy, moisture, sulfur, and ash content to ensure compatibility with gasification. While each source of biomass may have different properties, there are a few databases that can provide a general sense of the composition of various types of biomass. See

NREL's "Biomass Feedstock Composition and Property Database" (www1.eere.energy.gov/biomass/feedstock_databases.html).

"Phyllis" (www.ecn.nl/phyllis/) is another database of energy content and composition of various feedstocks compiled by the Energy Research Center of the Netherlands that may provide general estimates.

7.5 EMISSIONS REDUCTIONS, CAPITAL COST, PERMITS, INVOLVED PARTIES AND PARTNERSHIPS

This section includes information on emissions and emissions reductions associated with gasifiers, estimating capital costs, potential permit needs, potential parties that are involved in a digester project, and resources to develop partnerships.

Emissions Reductions[197]

Gasification systems emit very low emissions of SO_2, PM, and toxic compounds such as mercury, arsenic, selenium, and cadmium. The gasification process releases CO_2 but for non-fossil fuel feedstock, the net emissions are considered to be zero because it came from recently living things including grasses, trees, and agricultural crops that are continually being renewed. In other words, if forest residue was used in a gasifier, the same amount of CO_2 released from gasification should be taken up by new forest growth, assuming the biomass will be replanted. When syngas is then used to generate electricity, net emissions are negative since this offsets the emissions that otherwise would have been emitted from fossil fuel-powered utilities. Go to the EPA Power Profiler listed on page 112 to help determine emissions reductions from using syngas to generate electricity.

Capital Cost

According to the Bioenergy Feedstock Information Network, a large scale gasifier is estimated to cost about $1,000 per rated kW.[198] A 2000 NREL "Small Modular Biopower Initiative" document estimated that 25 kW—5 MW gasifiers have capital costs between $1,600 and $3,000 per rated kW.[199] At a per kWh basis, estimates range from 4.9-8.2 cents per kWh.

Permits

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

- Land use
- Air
- Wastewater
- Hazardous waste (ash)
- Water
- Storm-water management

Gasifier consultants should be able to help with permitting issues.

Involved Parties

Many sectors may be involved in planning, designing, operating, and managing a gasification project. Involved parties may include:

- Gasifier design companies
- Biomass suppliers
- Local utility
- US Department of Agriculture (USDA)
- Permitting officers
- Local agriculture/farming association or organization
- Investors

Finding Gasifier Partners

- California Integrated Waste Management Board: List of gasifier vendors. www.ciwmb.ca.gov/organics/conversion/Vendors/
- NREL: List of potential clean energy investors. www.nrel.gov/technologytransfer/entrepreneurs/directory.html

7.6 SUCCESS STORY

Mount Wachusett Community College, Gardner, Massachusetts[200]

Mount Wachusett Community College partnered with Community Power Corporation, NREL, and USDA Forrest Service to install a $1.2 million 50-kW woody biomass gasifier. The gasifier is fed 1.5 tons of wood chips per day and provides electricity to help power the school. Excess thermal energy is used for space heating and for cooling.

For more information, go to www.mwcc.edu/renewable/BiomassGasificationatMWCC.htm and www.delaware-energy.com/Download/BIO-MASS-CONF/Rob%20Rizzo.pdf.

CHAPTER 8: CLEANER DIESEL

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8.1 Importance of Reducing Diesel Emissions

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On cleanup and redevelopment sites, diesel engines are commonly used in soil removals and construction. Common construction equipment includes wheel loaders, skid steer loaders, wheel dozers, landfill compactors, excavators, backhoes, drill rigs, scrapers, and trucks. Diesel engines are highly durable and can last for about 30 years. While stringent diesel emissions rules are reducing emissions from newly manufactured engines, in-use older engines can continue to operate for many years. Diesel emissions, especially PM, are highly toxic, potentially exposing site workers and surrounding communities to increased health risks. Clean diesel technologies and alternative fuels can reduce harmful emissions from older, higher polluting engines. Clean diesel technologies include replacing, repowering, or retrofitting older engines with advanced emission control devices that significantly reduce harmful pollutants. The two most widely used retrofit technologies are diesel particulate filters (DPFs) and diesel oxidation catalysts (DOCs). Cleaner fuels like ultra-low-sulfur diesel (ULSD), and alternative fuels such as biodiesel, also reduce emissions. In addition, simple measures like idle reduction and engine maintenance can be practiced as fundamental components of reducing diesel pollution.

8.1 IMPORTANCE OF REDUCING DIESEL EMISSIONS

Reducing emissions from diesel engines is one of the most important air quality challenges facing the country. Diesel engines emit a complex mixture of air pollutants including both solid and gaseous materials that have serious human and environmental impacts (Table 7). EPA has deemed diesel exhaust as a “likely human carcinogen.”[202] California has also classified over 40 diesel exhaust pollutants as “toxic air contaminants.”[203] Diesel activities occurring at cleanup sites may expose workers and surrounding communities to diesel pollution. The diesel pollutants that cause the most public health concerns are PM and NO_x.

Table 7 Human and Environmental Health Risks from Diesel Pollutants[201]

Particulate Matter (PM)	Nitrogen Oxides (NO_x)
• Irritation of airways • Coughing • Difficulty breathing • Aggravated asthma • Decreased lung function • Lung and heart disease • Acute and chronic bronchitis • Irregular heartbeat • Heart attacks	• Acid Rain • Global warming • Water quality deterioration • Visibility impairments • Smog/precursor to ground-level ozone • Formation of toxic chemicals • Asthma in children • Increases lung susceptibility to toxins and microorganisms

Diesel pollution is a serious public health problem facing our country. The following are a few statistics that show the nationwide impacts of diesel emissions.

- In 2002, off-road diesel construction equipment emitted roughly 71,000 short tons of PM_{10}. About 95 percent of it was $PM_{2.5}$.[204]
- PM causes about 15,000 premature deaths a year. This is comparable to the number of deaths from 2nd-hand smoke and traffic accidents in California.[205]
- Diesel emissions result in approximately 6,000 children's asthma-related emergency room visits every year.[206]
- PM causes about 15,000 heart attacks per year.[207]
- In 2002, off-road diesel construction vehicles emitted about 764,000 tons of NO_x into our air.[208]
- EPA estimates that every $1 invested in diesel emissions reductions generates up to $13 in health-related benefits.[209]

For more information on EPA engine emissions standards, see the document *Reducing Air Pollution from Non-Road Engines* published in May 2003 by the EPA Office of Air and Radiation (www.epa.gov/OMS/cleaner-nonroad/f03011.pdf).

Key Diesel Pollutants

Particulate matter is the general term for a mixture of solid particles and liquid droplets found in the air.[211] Diesel engines emit particles smaller than 10 micrometers (μm) (PM_{10}) in diameter and nearly all are under 2.5 μm ($PM_{2.5}$) (Fig. 41). Human exposure to $PM_{2.5}$ is especially dangerous because these particles can penetrate deep into the lungs and cause serious problems including asthma, heart attacks, and even premature death.[212]

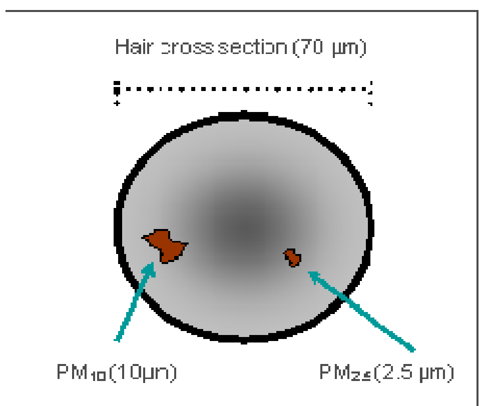

Figure 41 Size of diesel PM compared to a cross section of a human hair. Image courtesy EPA[210]

Nitrogen oxides (NO_x) is the term for a group of highly reactive gases that contain nitrogen and oxygen in varying amounts. NO_x form when fuel is burned at high temperatures, such as in a diesel engine. NO_x contribute to human health and environmental problems including asthma, smog, and acid rain (Table 7).

CO and SO_x pollutants are present in lower amounts in diesel exhaust compared to PM and NO_x but may also pose a risk to human health. CO can cause fatigue in healthy people and chest pain in people with heart disease. Exposure to moderate concentrations may cause angina, impaired vision, and reduced brain function. Higher concentrations can cause headaches, dizziness, confusion, nausea, and even death. SO_x can cause breathing problems for people with asthma. SO_x can also aggravate heart disease and induce respiratory illness and is a major component of ambient PM. In addition, this pollutant is a major component in acid rain formation, which harms ecosystems and degrades buildings and statues. Hydrocarbons (HC) are a precursor to ground-level ozone.

Go to the American Lung Association of California's website for more technical information on the health effects of diesel pollution (www.californialung.org/spotlight/cleanair03_research.html).

8.2 APPROACHES TO REDUCE DIESEL EMISSIONS

There are many technologies and practices that reduce diesel emissions. The following are some examples. More details on retrofits and cleaner fuels follow. See Section 10.10 (page 121) to calculate emissions and emissions reductions.

Retrofit engines with EPA or California Air Resources Board (CARB) verified diesel emission control technologies. Alternatively, try to select contractors or rental companies that have retrofitted or newer engines.

Maintain engines in accordance with engine manual (e.g., change air filters, check engine timing, fuel injectors and pumps) and keep engines well tuned.

Refuel with biodiesel, other alternative fuels, or with cleaner fuels such as ULSD. See page 74.

Modify Operations by reducing operating and idle time. A mid-sized off-road tractor may consume as much as one gallon of diesel fuel per hour of idling.[213] Reducing just one hour of idling from a typical back hoe loader can avoid about 13 grams of PM emissions, 155 grams of NO_x emissions, 65 grams of CO emissions, and 65 grams of CO_2 emissions.[214] For more details, go to www.epa.gov/otaq/smartway/idlingtechnologies.htm.

Replace/Repower existing engines with new cleaner diesel engines, hybrid engines, or engines compatible with alternative fuels.

See EPA's March 2007 publication, *Cleaner Diesels: Low Cost Ways to Reduce Emissions from Construction Equipment* (www.epa.gov/sectors/pdf/emission_0307.pdf) for more information on methods of reducing diesel pollution.

Diesel Engine Retrofits

Engines can be retrofitted with many kinds of emissions control devices. This section describes the most widely used technologies (Table 8). See Appendix VIII (page 150) to see which verified retrofit technologies may be applicable for off-road equipment used at your site.

Diesel Particulate Filters (DPFs)

DPFs use ceramic filters to collect diesel PM from engine exhaust (Fig. 42, Fig. 43). Over time, PM builds up on the filters and they must be cleaned or "regenerated."[217] For some DPFs, high enough engine exhaust temperatures can clean the filters by oxidizing (breaking down) the PM into less harmful components of CO_2 and water vapor.[218] These DPFs are called passive DPFs. Active DPFs require more maintenance because they must be removed for regeneration. DPFs require ULSD since sulfur reduces the effectiveness of DPFs.

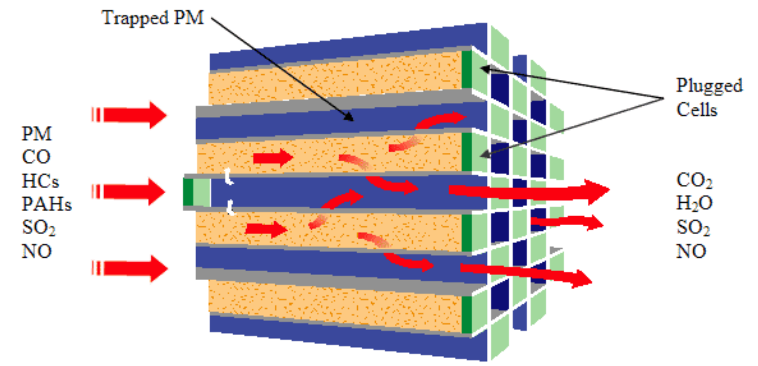

Figure 42 Schematic of DPF. Image courtesy MECA[215]

Figure 43 Dozer installed with DPF. Image courtesy EPA,[216]

Diesel Oxidation Catalysts (DOCs)

DOCs have been installed in off-road engines for over 30 years to reduce PM emissions. DOCs usually consist of a stainless steel container that holds a honeycomb structure (Fig. 44, Fig. 45). The interior surfaces are coated with catalytic metals such as platinum or palladium. Chemical oxidation reactions convert exhaust gas pollutants into less harmful gases. While many older engines are not compatible with passive DPFs, DOCs are able to work with these higher polluting engines.

Figure 44 Schematic of DOC. Image courtesy MECA[219]

Selective Catalytic Reduction (SCR)[221]

While DOCs and DPFs concentrate on reducing PM emissions, SCRs are best at reducing NO_x emissions and reduce PM and HC as well. NO_x are converted to molecular nitrogen and oxygen in the SCR. A stream of ammonia or urea added to the exhaust gases pass over an SCR catalyst and cause chemical reactions that reduce NO_x emissions. SCRs greatly reduce odor caused by diesel engines and diesel smoke. SCR catalysts may also be combined with DOCs or DPFs for additional PM emissions reductions.

Figure 45 Dozer with DOC retrofit.
Image courtesy Schattanek[220]

Exhaust Gas Recirculation (EGR)

Diesel engines may be equipped with EGR devices to lower NO_x formation. Engine combustion chambers can reach temperatures greater than 2,500°F. At these temperatures, nitrogen and oxygen react to form NO_X which contribute to smog. An EGR device recirculates exhaust into the air intake stream. These gases displace some of the normal intake, lowering the peak temperature of the combustion process by hundreds of degrees and reduce the amount of oxygen available to form NO_x.[222] However, EGR increases PM emissions and are not compatible with many verified DOCs and DPFs for off-road engines.[223]

Table 8 Diesel Engine Retrofit Options

	Diesel Particulate Filter (DPF)	Diesel Oxidation Catalyst (DOC)	Selective Catalytic Reduction (SCR)
Technology Description	Wall-flow type filter installed in the exhaust system, much like a muffler, in which PM emissions are trapped. Active DPFs require regular maintenance to regenerate or burn off accumulated PM, when the engine is not in use. Passive DPFs regenerate during engine operation if exhaust temperature requirements are met.	Canister-like device containing a honeycomb structure that is installed in the exhaust system. A catalyst oxidizes CO and HC as the exhaust flows through, which breaks them down into less harmful components.	Device that injects urea, or some form of ammonia, into the exhaust stream and reacts over a catalyst to reduce NO_x emissions.
Cost per retrofit	\$7,000—\$10,000[224]	\$500—\$2,000[225]	\$12,000 with DOC \$20,000 with DPF[226]
Emissions Reductions	PM reduced 60%-90%[227] HC reduced 60%-90%[228] CO reduced 60%-90%[229]	PM reduced 40%-50%[230]	SCR without DOC or DPF PM reduced 30%-50%[231] NO_x reduced 75%-90% HC reduced 50%-90%
Benefits	Can be coupled with an exhaust gas recirculation system (page 71) to further reduce NO_x (up to 40%) and PM (up to 85%) though may not be compatible with currently verified DPFs[232] Can also be coupled with a SCR to reduce NO_x and PM	Should not decrease fuel economy, shorten engine life, nor adversely affect drivability Less restrictive than DPF because DOCs are less affected by exhaust buildup in the filter Works well with older, higher emitting engines Use of ULSD increases efficiency	Commonly used in stationary applications. Often used with a DOC or catalyzed DPF to achieve greater PM reductions
Considerations	Annual maintenance costs approximately \$150-\$310[233] Active DPFs require maintenance to keep filters clean. Passive DPFs oxidize PM via catalysts or high exhaust temperatures Off-road engines may require active DPFs Diesel equipment needs to meet minimum temperature requirements specific to individual filter technologies Slight fuel economy penalty from pressure buildup in the exhaust system, pressure and temperature monitors are necessary Requires ULSD 1995 and older engines may overload passive filters but may be compatible with active regeneration systems	May suffer thermal degradation when exposed to temperatures above 650˚C for prolonged periods of time but these are unlikely conditions during normal operation[234] Requires normal exhaust maintenance	Requires periodic refilling of an ammonia or urea tank Requires low-sulfur diesel or ULSD

Retrofitting a Fleet

The following steps provide an approach to retrofitting a fleet.

Step 1

Inventory the fleet for each engine and determine the following:

- Type of equipment (backhoe, generator, etc.)
- Engine year, make, model, horsepower, displacement
- Engine family name (See Appendix VIII page 152)
- If a diesel emissions reduction device is already in place. New engines may have one installed.
- Turbocharged or naturally aspirated
- Mechanically or electrically controlled
- If it employs exhaust gas recirculation (page 71)

Step 2

Visit the EPA (www.epa.gov/otaq/retrofit/verif-list.htm) and CARB (www.arb.ca.gov/diesel/verdev/vt/cvt.htm) verification websites to determine compatible retrofit devices. See Appendix VIII (page 150) for verified retrofit technologies for off-road mobile engines.

Step 3

Work with vendors to assess the compatibility of your diesel equipment with a retrofit. They may need additional information such as: location for mounting retrofit device (on the muffler or on the side of the vehicle), size of the exhaust system, and if any changes will be made to the exhaust system (sometimes the retrofit device does not replace the muffler).

Step 4

Typically, datalogging is required before installing a DPF to determine if the exhaust temperatures are sufficient for passive DPF systems. Passive filters require high exhaust temperatures to oxidize the soot that accumulates on the filter. Vendors will datalog temperature information for a few days on each engine to see if required temperature minimums are met. Datalogging may cost about $200-$300 for two to three days of monitoring. Active DPF systems do not require high exhaust temperatures but do require maintenance.

Important Notes on Retrofitting

- Equipment retrofitted with DPFs should always include a device to monitor the increased pressure buildup in the exhaust system. These devices, called back-pressure monitoring systems, may also be installed with DOCs. A warning light in the cab will notify the equipment operator if the pressure becomes too high and maintenance is necessary.

- Retrofits may take place on-site or at the dealership, depending on the contract with the dealer.
- It is generally not recommended to remove a retrofit device from an engine for which it was designed and use it on another engine. Though this is possible if the engines are similar, it may not be in proper verified use, and may result in damage to the engine or retrofit device.
- DPFs may take from 1.5 hours to a full day to install. DOCs usually take 1.5-4 hours to install. Installations cost from $170 to $500 for each engine for both DOCs and DPFs.[235]
- SCRs require installation of a tank for ammonia (or other reagent), as well as the necessary catalyst and associated piping and controls. These retrofits can be much more involved compared to DPFs or DOCs. A dependable source of ammonia or urea supply is also required.

Cleaner and Alternative Fuels

Using cleaner and alternative fuels also helps to minimize diesel pollution. Most retrofit technologies require the use of low- or ultra-low-sulfur diesel. Many retrofits are also compatible with low blends of biodiesel. The following are commonly used cleaner and alternative fuels (Table 9). For information on where these fuels are available, go to www.eere.energy.gov/afdc/fuels/stations.html.

Ultra-Low-Sulfur Diesel (ULSD)

EPA's Clean Air Highway Diesel rule, finalized in 2001, requires a 97 percent reduction in the sulfur content of highway diesel fuel, from 500 ppm in low-sulfur diesel (LSD), to 15 ppm in ULSD (Fig. 46). While on-road diesel vehicles are already required to fuel with ULSD, off-road equipment ULSD fueling requirements begin in 2010. Highway model year 2007 and later engines must use ULSD to function properly. California's stricter rules already require ULSD in both off- and on-road engines.[237] Use ULSD in both on-road and off-road equipment used in site cleanup and redevelopment activities to reduce PM emissions by about 13 percent compared to LSD.[238] ULSD costs about 4-5 cents more per gallon to produce and distribute.[239] Some diesel fuel may be colored red. The red dye is added to non-taxed off-road diesel to distinguish it from clear, or "white," taxed on-road diesel.[240]

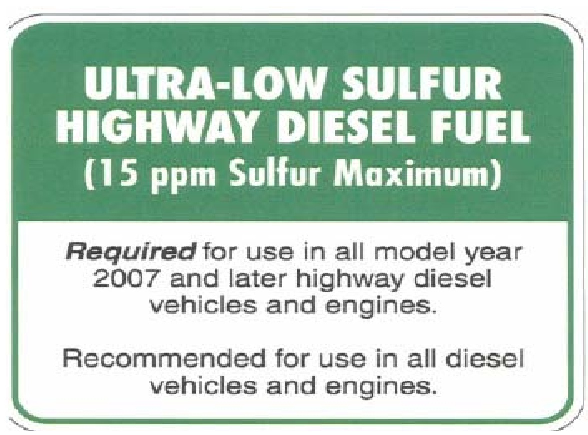

Figure 46 ULSD pump label. Image courtesy EPA[236]

Biodiesel

Biodiesel is a renewable fuel made from agricultural products such as vegetable oils. While most biodiesel is made from soybean oil in the United States, biodiesel made with canola oil and sunflower oil are also available. Biodiesel can also be produced from recycled cooking oils and animal fats, which is less energy-intensive than biofuel made from virgin crops. Biodiesel is not pure vegetable oil or animal fats. The oil must be refined through a process called *esterification* in which an industrial alcohol and a catalyst convert the oil into biodiesel.[241] Use biodiesel that conforms to ASTM standards to ensure that it performs properly.[*]

Biodiesel is often blended with conventional diesel in varying amounts. Biodiesel labeled "B20" is composed of 20 percent biodiesel and 80 percent conventional diesel and "B5" biodiesel is 5 percent biodiesel and 95 percent conventional diesel, etc. Biodiesel blends with ULSD will yield greater emission reductions. Most engines are compatible with biodiesel blends up to B20. Check with the manufacturer or rental company for recommendations and/or warranty issues. Biodiesel may release accumulated deposits from fuel tank walls and pipes, potentially causing clogs in the fuel filter. The fuel filter should be changed after the first tank of biodiesel. Some rubber fuel system components may also need to be replaced with biodiesel-compatible rubber, especially in older engines.

Compared to petrodiesel, biodiesel reduces PM, GHGs, sulfates, and HC. Go to Section 10.10 (page 121) to calculate your emissions reductions. Some DPFs may be compatible with biodiesel and may provide additional reductions compared with using ULSD.[242] As a consideration, some studies have shown a slight increase in NO_x while others show a slight decrease NO_x emissions from using biodiesel compared with conventional diesel. Further investigation is planned to yield more conclusive results.[243] Also, using B20 may result in a slight fuel economy loss of around one to two percent compared to fueling with petrodiesel.[244]

Go to www.epa.gov/smartway/growandgo/documents/factsheet-biodiesel.htm for more information on benefits of biodiesel and how it is produced.

Find biodiesel fueling stations at the National Biodiesel Board website (www.biodiesel.org/buyingbiodiesel/distributors/).

Natural Gas

Natural gas burns cleaner than gasoline or diesel but must be used in vehicles with specially-designed engines. It emits 90 percent less PM and CO compared to diesel. However, natural gas is mostly CH_4, a GHG. Some studies show that there are no GHG reductions from using natural gas—the CO_2 reductions are offset by escaping CH_4.[245] It is important to ensure that there are no leaks in the tanks. Natural gas can be used in vehicles as compressed natural gas (CNG) or liquefied natural gas (LNG). CNG is natural gas pressurized to 3,600 pounds per square inch and LNG is natural gas condensed to its liquid state by cooling it to -260°F.[246]

A wide range of light-duty vehicles that run on CNG are available. While natural gas engines are not available for off-road heavy-duty equipment, there are natural gas options for hauling-trucks. Search

[*] ASTM International is an international organization that develops standards for a wide variety of materials and products. Biodiesel should comply with ASTM D6751 standards.

for natural gas vehicles at the EERE Alternative Fuels and Advanced Vehicles Data Center website (www.eere.energy.gov/afdc/afv/afdc_vehicle_search.php).

CNG is a cleaner burning fuel which reduces maintenance costs compared with conventional diesel engines.[247] Note that CNG cylinders must be inspected every 36 months or 36,000 miles. Go to the Clean Vehicle Education Foundation website for more information on natural gas vehicles (www.cleanvehicle.org/technology/cylinder.shtml).

Go to www.eere.energy.gov/afdc/fuels/natural_gas.html for more information on natural gas.

Emulsified Diesel Fuel

Emulsified diesel is a mixture of diesel fuel, water, and other additives which lowers combustion temperatures to reduce PM and NO_x emissions.[248] The water content in emulsified fuels is between 5 and 30 percent. This fuel can be used in any diesel engine though some power and fuel economy losses may be expected. While emulsified diesel stays well mixed for a fairly long time, the water may settle out after a few months of dormancy.[249]

Find verified emulsified fuels at the following websites:

- EPA Verified Diesel Retrofit Technology www.epa.gov/otaq/retrofit/verif-list.htm
- CARB Verified Diesel Retrofit Technology www.arb.ca.gov/diesel/verdev/vt/cvt.htm

Table 9 Cleaner and Alternative Fuels

	Ultra-Low-Sulfur Diesel	**Biodiesel**	**Natural Gas**	**Emulsified Fuel**
Fuel Description	Ultra-low-sulfur diesel (ULSD) has less than 15 ppm sulfur content. Low-sulfur diesel (LSD) contains less than 500 ppm sulfur content.	Renewable fuel made from animal or vegetable fats. Can be blended with conventional diesel. Usually found in 2% (B2), 20% (B20), and 100% (B100) blends.	Gas consisting mainly of methane. In the forms of compressed natural gas and liquefied natural gas.	Fuel that is mixed with water and additives to lower combustion temperatures which reduces NO_x and PM. Refer to the CARB verified list for qualified emulsified fuels.
Emissions Reductions (compared to low-sulfur diesel)	PM 13%[250] NO_x 3%[251] CO 6%[252] HC 13%[253]	B20 PM 10%[254] NO_x* -2%[255] CO 10%[256] HC 21%[257] Sulfates 20%[258] CO_2 15%[259]	PM 90%[260] NO_x 50%[261] CO 90%[262] HC 50 to 75%[263] CO_2 25%[264]	PM 16 to 58%[265] NO_x 9 to 20%[266] CO 13%[267] HC -30 to -99%[268]
Cost	$0.04 -$0.05 more per gallon than low-sulfur diesel[269]	As of July '07, B20 was the same price as conventional diesel[270]	~15 to 40% less than gasoline per gallon[271]	~$0.20 more per gallon than conventional diesel[272]
Considerations	Most verified retrofit technologies require the use of LSD or ULSD. In June 2006, CARB mandated the use of ULSD in both on- and off-road vehicles in California. Nationwide mandates for ULSD use in on-road engines came into effect in 2006 and mandates for LSD use in off-road vehicles came into effect in 2007.	Biodiesel blends lower than B20 experience insignificant difference in torque, horsepower, and fuel economy compared to conventional diesel. Using higher biodiesel blends may require changing fuel filters and replacement of rubber compound fuel system components with compatible rubber. Use biodiesel that meets the ASTM D6751 standard. Monitor performance in cold weather operation and ensure proper additives are used to prevent gelling.	Needs more frequent fueling. Natural gas vehicles cost about $3,500 to $6,000 more than gasoline equivalents.[273]	May affect horsepower in some applications. Can be used in any diesel engine.

*NREL and EPA are conducting further evaluations to determine potential NO_x increase.

8.3 CLEAN DIESEL SAMPLE LANGUAGE AND RELEVANT LAWS AND REGULATIONS[274]

This section includes information on sample language used in contracts that may be useful when writing task orders. Some current state laws and regulations that address diesel emissions are also listed.

Sample Cleaner Diesel Language

Many areas of the country are placing clean diesel language in contracts, codes, laws, rules and other measures to reduce emissions from construction equipment and other diesel sources. Go to www.epa.gov/cleandiesel/construction/contract-lang.htm for examples of language that address air quality issues, particularly diesel emissions, from construction equipment and other diesel sources.

Laws and Regulations

The following are some state incentives and laws concerning alternative fuels and clean diesel practices. As of the writing of this document, no relevant laws were found for Hawaii, Nevada, or the Pacific Islands. Go to www.eere.energy.gov/afdc/laws/incen_laws.html for a more comprehensive list of state and local incentives and rules.

Arizona

- Alternative Fuel and Alternative Fuel Vehicle (AFV) Tax Exemption: The Arizona Use-Tax does not apply to the following: natural gas or liquefied petroleum gas used in motor vehicles; AFVs if the AFV was manufactured as a diesel fuel vehicle and converted to operate on an alternative fuel; and equipment that is installed in a conventional diesel fuel motor vehicle to convert the vehicle to operate on an alternative fuel.
- Alternative Fuel Vehicle License Tax: The initial annual vehicle license tax on an AFV is lower than the license tax on conventional vehicles. The vehicle license tax on an AFV is $4 for every $100 in assessed value. The assessed value of the AFV is determined as follows: during the first year after initial registration, the value of the AFV is one percent of the manufacturer's base retail price (as compared to 60 percent for conventional vehicles); during each succeeding year, the value of the AFV is reduced by 15 percent. The minimum amount of the license tax is $5 per year for each motor vehicle subject to the tax.
- Alternative Fuel Vehicle Special License Plate: AFVs must display an AFV license plate. State or agency directors who conduct activities of a confidential nature and have a vehicle powered by an alternative fuel are exempt from the requirement of displaying an AFV special license plate. The Arizona Department of Transportation has the authority to issue regular plates to AFVs that are used by law enforcement and the federal government.
- Clean Fuel Diesel for Heavy-Duty Equipment: Any state agency that contracts for the use of on- or off-road heavy-duty diesel equipment in Maricopa County, Pima County, and Pinal County must construct its Requests for Proposals in a manner that gives incentives to bidders that use:

equipment retrofitted with diesel retrofit kits; newer clean diesel technologies and fuels; or biodiesel or other cleaner petroleum diesel alternatives.

- Idle Reduction Requirement: Heavy-duty diesel vehicles operated in Maricopa County with a gross vehicle weight rating of more than 14,000 pounds must limit idling time to no more than 5 minutes. Exemptions apply for emergency vehicles, certain traffic or weather conditions, certain driver accommodations, and idling necessary for refrigeration equipment.

California

- Idle Reduction Requirement – Trucks: The new engine requirements call for 2008 and newer model year heavy duty diesel engines to be equipped with a non-programmable engine shutdown system that automatically shuts down the engine after 5 minutes of idling or optionally meets a 30 gram per hour NO_x idling emission standard. The in-use truck rules require operators of sleeper berth-equipped trucks to manually shut down their engine when idling more than 5 minutes at any location within California beginning in 2008. The penalty for violating this measure is $100 per violation.

- In-Use Off-Road Diesel Vehicle Regulation: This regulation establishes fleet average emission rates for PM and NO_x that decline over time. Each year, the regulation requires each fleet to meet the fleet average emission rate targets for PM or apply the highest level verified diesel emission control system to 20 percent of its total horsepower. In addition, large and medium fleets are required each year to meet the fleet average emission rate targets for NO_x or to "turn over" a certain percent of their horsepower. "Turn over" means repowering with a cleaner engine, retiring a vehicle, replacing a vehicle with a new or used piece, or designating a dirty vehicle as a low-use vehicle. If retrofits that reduce NO_x emissions become available, they may be used in lieu of turnover as long as they achieve the same emission benefits.

    - Large fleet (>5,000 hp) first average compliance date: 2010
    - Medium fleet (2,501 hp – 5,000 hp) first average compliance date: 2013
    - Small fleet (≤2,500 hp) first average compliance date: 2015

  For more information on this regulation, go to www.arb.ca.gov/msprog/ordiesel/ordiesel.htm.

8.4 SUCCESS STORIES

AMCO Superfund Site, Oakland, CA, Region 9

The AMCO Superfund site was owned and operated by AMCO Chemical as a chemical distribution facility from the 1960s to 1989. Removal of lead soil in residential neighborhoods occurred in the summer of 2007. The mini-excavator and skid-steer used on the site were fueled with a B10 biodiesel blend. The biodiesel was picked up from a biodiesel distributor about 6 miles away from the site. The rental company allowed a maximum of 10 percent biodiesel blend fuel to be used in their equipment, although there are usually no technological barriers to using a higher blend. In total, this removal used 150 gallons of B10. No issues were encountered with the use of B10 in the equipment used at the AMCO removal. The use of biodiesel avoided 45 grams of PM emissions.

Site Contact:
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Camp Pendleton Marine Corps Base, Superfund Site, about 40 miles north of San Diego, CA, Region 9

Camp Pendleton Marine Corps Base has nine areas of soil and groundwater contamination due to past disposal practices. From late 2007 to early 2008, 120,000 ft^3 of soil were excavated and removed. Camp Pendleton made efforts to use newer engines, biodiesel, and to retrofit engines with DPFs for the excavation. Two pieces of equipment had the latest (Tier 3[†]) technology and were retrofitted with DPFs. Four pieces of equipment had the latest (Tier 3) technology and were fueled with B20. Two pieces of equipment were fueled with B5. The retrofits and DPFs reduced PM emissions by 27 percent. Compared to Tier 1 engines, Tier 3 engines emit 63 percent less PM.

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[†] Tiers are levels of federal emissions standards that vary depending on vehicle type, size, and year of manufacture. Higher tiers are stricter than lower tiers. For more information, go to www.dieselnet.com/standards/.

CHAPTER 9: FUNDING RESOURCES AND OPPORTUNITIES

This chapter includes resources that provide information on funding opportunities for energy efficiency, renewable energy technologies, and diesel emissions reductions efforts. Details are provided for some national, regional, and state-wide incentives that are applicable in Region 9 (local incentives are not included). See Table 10 for a chart that summarizes these opportunities. This chart provides a quick overview on the type of funding and technology, sector, and geographic applicability. Details such as funding amounts, requirements, and contact information on the funding opportunities listed are included following the chart.

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9.1 RESOURCES FOR FINDING FUNDING OPPORTUNITIES AND FUNDING OPPORTUNITIES CHART

Below is a list of resources for finding funding opportunities for energy efficiency, renewable energy, and diesel emissions reduction efforts. Check these resources for national, regional, state, county, and local funding opportunities. See Table 10 for a chart summarizing some national, regional, and state-wide incentives found through these resources.

- Clean Diesel Technology Forum: Funding resources for diesel emissions reductions efforts. www.dieselforum.org/retrofit-tool-kit-homepage/retrofit-grants/
- Database of State Incentives for Renewables and Efficiency by North Carolina State University: Includes national, regional, state and local funding opportunities. www.dsireusa.org
- DOE E-Center Business and Financial Opportunities with Energy: Energy efficiency and renewable energy funding resources. http://e-center.doe.gov/
- EERE Federal Energy Management Program (FEMP): Incentives database for energy efficiency improvements. www1.eere.energy.gov/femp/program/utility/utilityman_energymanage.html
- *Emission Reduction Incentives for Off-Road Diesel Equipment Used in the Port and Construction Sectors:* Report of diesel emissions reduction funding opportunities prepared for EPA by ICF Consulting published in May 2005. www.epa.gov/sectors/pdf/emission_20050519.pdf
- Federal grants: Search for energy efficiency, renewable energy, and cleaner diesel federal grants. http://grants.gov

- *Funding On-Farm Biogas Recovery Systems: A Guide to Federal and State Resources:* Funding opportunities for anaerobic digesters published by the AgStar Program. www.epa.gov/agstar/pdf/ag_fund_doc.pdf
- *Funding Opportunities: A Directory of Energy Efficiency, Renewable Energy and Environmental Assistance Programs*: Document by the EPA State and Local Capacity Building Branch published September 2006. www.dep.state.pa.us/dep/deputate/pollprev/PDF/FundingOpportunities.pdf
- LMOP Funding Guide: Funding opportunities for landfill gas-to-energy projects. www.epa.gov/lmop/res/guide/index.htm
- NREL Solicitations and Request for Proposals: Renewable energy funding opportunities. www.nrel.gov/business_opportunities/solicitations_rfps.html
- Tax Incentives Assistance Project: Service provided by a coalition of public interest nonprofit groups, government agencies, and other organizations in the energy efficiency field for information on energy efficiency and renewable energy tax incentives. www.energytaxincentives.org/
- West Coast Diesel Collaborative: List of funding opportunities for diesel emissions reductions efforts. www.westcoastcollaborative.org/grants and http://westcoastcollaborative.org/fed-funding.htm

Table 10 Summary of National, Regional, and State Funding Opportunities for Cleaner Energy and Diesel

Funding Program	Applicability	Type of Funding	Applicable Sector	Energy Efficiency	Solar	Wind	Landfill Gas	Digester	Gasifier	Cleaner Diesel
Air Pollution Control Program Support *EPA* p. 88	National	Grant	State, tribal, municipal, intermunicipal, and interstate agencies							X
Biodiesel Tax Credit *IRS* p. 88	National	Tax Credit	Biodiesel producers							X
Clean Renewable Energy Bonds (CREBs) *IRS* p. 88	National	"Interest-Free" Loan	Governmental bodies and mutual or cooperative electric companies		X	X	X	X	X	
Congestion Mitigation Air Quality (CMAQ) Improvement Program *U.S. Department of Transportation (DOT)* p.88	National	Various	State DOTs, metropolitan planning organizations, and transit agencies							X
Conservation Innovation Grants (CIG) *USDA Natural Resources Conservation Service* p. 89	National	Grant	Non-federal governmental and non-governmental organizations, tribes, and individuals					X	X	
Consolidated Research/Training Grants *EPA Office of Research and Development* p. 89	National	Grant	State, territory and possession of the U.S., District of Columbia, universities and colleges, hospitals, laboratories, local government, tribes, and nonprofit institutions							X
Environmental Quality Incentives Program (EQIP) *USDA Natural Resources Conservation Service* p. 90	National	Cost-Share	Agricultural producers					X	X	
Farm Pilot Project Coordination (FPPC), Inc. p. 91	National	Grant	Agricultural producers					X	X	

Funding Program	Applicability	Type of Funding	Applicable Sector	Energy Efficiency	Solar	Wind	Landfill Gas	Digester	Gasifier	Cleaner Diesel
Federal Tax Credit (Business Energy Tax Credit) *IRS* p. 91	National	Tax Credit	Commercial and residential		x		x	x	x	
Modified Accelerated Cost-Recovery System (MACRS) *IRS* p. 92	National	Depreciation Deduction	Commercial and industrial		x	x	x	x	x	
National Clean Diesel Campaign (NCDC) *EPA* p. 92	National	Various	Various							x
Pollution Prevention (P2) Grants Program *EPA Office of Pollution Prevention and Toxics* p. 93	National	Grant	States, the District of Columbia, any territory or possession of the U.S., any agency or instrumentality of a state including state colleges, universities, and indian tribes							x
Public Interest Energy Research (PIER) Program *California Energy Commission* p. 93	National	Various	Commercial	x	x	x	x	x	x	
Renewable Electricity Production Tax Credit (REPC) *IRS* p. 94	National	Tax Credit	Various			x	x	x	x	
Renewable Energy Systems and Energy Efficiency Improvements Program *U.S. Department of Agriculture (USDA)* p. 95	National	Various	Agricultural producers or rural small businesses	x	x	x	x	x	x	

Funding Program	Applicability	Type of Funding	Applicable Sector	Energy Efficiency	Solar	Wind	Landfill Gas	Digester	Gasifier	Cleaner Diesel
Renewable Energy Production Incentive (REPI) *IRS* p. 96	National	Payment Incentive	Not-for-profit electrical cooperatives, public utilities, state governments, commonwealths, U.S. territories, tribal governments		**x**	**x**	**x**	**x**	**x**	
Renewable Energy Grants and Loans Programs *USDA Rural Development* p. 97	National	Various	Corporations, states, territories, and subdivisions and agencies thereof, municipalities, people's utility districts, and cooperative, non-profit, limited-dividend or mutual associations that provide retail or power supply service needs in rural areas	**x**	**x**	**x**	**x**	**x**	**x**	
Sustainable Agriculture Research and Education (SARE) Grants *USDA Cooperative State Research, Education, and Extension Service* p. 97	National	Grant	Researchers, agricultural educators, farmers and ranchers, and students					**x**	**x**	
West Coast Collaborative *EPA* p. 98	CA, OR, WA, AL, AZ, ID, NV, HI, Canada, Mexico	Grants	Public institutions, non-profit organizations, universities, and tribes							**x**
Commercial/Industrial Solar & Wind Tax Credit (Corporate) *AZ Dept. of Commerce* p. 98	AZ	Tax Credit	Businesses		**x**	**x**				
California Emerging Renewables Program (ERP) *California Energy Commission* p. 99	CA	Rebate	Customers of PG&E, SCE, SDG&E, or BVE			**x**	**x**	**x**	**x**	

Funding Program	Applicability	Type of Funding	Applicable Sector	Energy Efficiency	Solar	Wind	Landfill Gas	Digester	Gasifier	Cleaner Diesel
California Solar Initiative (CSI) *California Public Utilities Commission* p. 100	CA	Payment Incentive	Governmental bodies, non-profits, residential, business		x					
Carl Moyer Memorial Air Quality Standards Attainment Program *CARB* p. 103	CA	Grant	Any public or private entity							x
Energy Efficiency and Renewable Generation Emerging Technologies, Agriculture and Food Industries Loan Program *California Energy Commission* p. 103	CA	Loan	Agricultural and food processing industries		x			x	x	
Self Generation Incentive Program (SGIP) *California Public Utilities Commission* p. 104	CA	Rebate	Customer of PG&E, SCE, SDG&E, or SCGC			x	x	x	x	
Hawaii Renewable Energy Tax Credits OR Capital Goods Excise Tax *State of Hawaii, Department of Business, Economic Development and Tourism* p. 106	HI	Tax Credit	Commercial and residential		x	x				
Renewable Energy Producers Property Tax Abatement *Nevada Commission on Economic Development* p. 107	NV	Tax Abatement	New or expanded commercial businesses		x	x	x	x	x	
Renewable Energy Systems Property Tax Exemption *Nevada Department of Taxation* p. 107	NV	Tax Exemption	Commercial and industrial		x					

Funding Program	Applicability	Type of Funding	Applicable Sector	Energy Efficiency	Solar	Wind	Landfill Gas	Digester	Gasifier	Cleaner Diesel
Solar Generations PV Rebate Program *Sierra Pacific & Nevada Power Companies* p. 108	NV	Rebate	Commercial, residential, schools, local government, state government, other public buildings		**x**					

9.2 NATIONAL FUNDING

- Air Pollution Control Program Support, EPA

  This program assists state, tribal, municipal, intermunicipal, and interstate agencies in implementation of national primary and secondary air quality standards. It is also a resource that can assist in planning, developing, establishing, improving, and maintaining adequate programs for prevention and air pollution control.

  Go to the Catalog of Federal Domestic Assistance listing for details: http://12.46.245.173/pls/portal30/CATALOG.PROGRAM_TEXT_RPT.SHOW?p_arg_names=prog_nbr&p_arg_values=66.001.

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- Biodiesel Tax Credit, IRS

  In 2005, Congress granted federal tax credits for biodiesel producers. The tax credit is 50¢ per gallon of biodiesel (recycled cooking oil) and $1 per gallon for “agri-biodiesel” (virgin vegetable oil). Biodiesel producers claim the credit by filling out IRS Form 8864 (www.irs.gov/pub/irs-pdf/f8864.pdf).

  Go to www.biodiesel.org/news/taxincentive/ for more information.

- Clean Renewable Energy Bonds (CREBs), IRS

  CREBs offer a source of funding for renewable energy projects by providing essentially an interest free loan for a renewable energy project. The IRS allocates bonds to qualified lending authorities. Governmental bodies and mutual or cooperative electric companies are eligible to apply for the bonds as a funding source for renewable energy projects. These bonds are designed to be “interest free” because the holder is given a tax credit for the interest. The Tax Relief and Health Care Act of 2006 extended issuance of CREBs until December 31, 2008. Check the IRS website for future extensions.

  For more details, go to www.irs.gov/irb/2007-14_IRB/ar17.html and www.elpc.org/energy/farm/crebs.php.

  For more information on CREBs, call the IRS Office of Associate Chief Counsel (Tax Exempt & Government Entities) at (202) 622-3980.

- Congestion Mitigation and Air Quality (CMAQ) Improvement Program, U.S. Department of Transportation (DOT)

  The CMAQ Improvement Program provides financial assistance to areas striving to attain federal air quality standards. State DOTs, metropolitan planning organizations (MPOs), and transit agencies can invest more than $1.6 billion annually until 2009 in projects that reduce criteria air pollutants regulated from transportation-related sources. Clean diesel retrofit projects are eligible for CMAQ consideration.

CMAQ funds are available only to National Ambient Air Quality Standards non-attainment and maintenance areas .

While $1.6 billion are available on a nationwide basis, areas should consult the CMAQ program and their state DOT and MPOs to determine how much CMAQ funding is available (funds are allocated to areas according to population and severity of non-attainment designation).

Under the 2005 re-authorization of the CMAQ program, diesel engine retrofits were given high priority for CMAQ funding.

For more information, go to www.fhwa.dot.gov/environment/cmaqpgs/.

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- Conservation Innovation Grants (CIG), USDA Natural Resources Conservation Service

The CIG program is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging federal investment in environmental enhancement and protection, in conjunction with agricultural production. Biomass-to-energy projects may qualify.

- Eligible applicants include: non-federal governmental or non-governmental organizations, Tribes, or individuals.
- CIG usually has two competitions—National and State.
- National categories for potential projects change year to year. FY 2007 offered a National Technology Category that included methane recovery as a subtopic.

For details, go to www.nrcs.usda.gov/programs/cig/.

For Region 9, only California (www.ca.nrcs.usda.gov/programs/cig/) and Hawaii (www.hi.nrcs.usda.gov/programs/cig/index.html) are participating.

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- Consolidated Research/Training Grant, EPA ORD

The Consolidated Research/Training Grant supports research and development to determine the environmental effects of air quality, drinking water, water quality, hazardous waste, toxic substances, and pesticides. It is available for each state, territory and possession, and tribal nation of the U.S., including the District of Columbia, for public and private state universities and colleges, hospitals, laboratories, state and local government departments, other public or private nonprofit institutions, and in some cases, individuals who have demonstrated unusually high scientific ability.

Go to the Catalog of Federal Domestic Assistance listing for details: http://12.46.245.173/pls/portal30/CATALOG.PROGRAM_TEXT_RPT.SHOW?p_arg_names=prog_nbr&p_arg_values=66.511.

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- Environmental Quality Incentives Program (EQIP), USDA Natural Resources Conservation Service

EQIP is a voluntary program that provides assistance to farmers and ranchers who face threats to soil, water, air, and related natural resources on their land. EQIP was reauthorized in the Farm Security and Rural Investment Act of 2002 (Farm Bill). Persons who are engaged in livestock or agricultural production on eligible land may participate in the EQIP program.

EQIP may cost-share up to 75 percent of the costs of certain conservation practices. Incentive payments may be provided for up to three years to encourage producers to carry out management practices they may not otherwise use without the incentive. However, limited resource producers and beginning farmers and ranchers may be eligible for cost-shares up to 90 percent. Farmers and ranchers may elect to use a certified third-party provider for technical assistance. An individual or entity may not receive, directly or indirectly, cost-share or incentive payments that, in the aggregate, exceed $450,000 for all EQIP contracts entered during the term of the Farm Bill.

Some EQIP Requirements:

- Only land that has been irrigated for two of the last 5 years prior to application for assistance will be eligible for cost-share or incentive payments for irrigation related structural and land management practices.
- Funding may be used towards improving land management practices, such as nutrient management, manure management, integrated pest management, irrigation water management, wildlife habitat enhancement, and developing comprehensive nutrient management plans.
- Producers who are engaged in crop or livestock production on eligible land are eligible for the program. Eligible land includes cropland, rangeland, pasture, private non-industrial forestland, and other farm or ranch lands, as determined by the Secretary of Agriculture.

For more information, go to www.nrcs.usda.gov/programs/eqip/.

Arizona
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Nevada
www.nv.nrcs.usda.gov/programs/eqip2006.html
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Resource Conservationist, Programs
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- Farm Pilot Project Coordination, Inc. (FPPC)

FPPC, a non-profit organization, was designated by Congress (Public Law 107-76) to assist in implementing innovative treatment technologies to address the growing waste issues associated with animal feeding operations (AFO). FPPC's objective is to foster the conservation, development and wise use of land, water, and related resources, while providing AFOs with opportunities for profitable operation. Funding for approved pilot projects comes from monies appropriated by Congress and overseen by the Natural Resource Conservation Service, a division of the USDA. Requests for proposals are issued about twice a year. FPPC grants approximately $2-$3 million per RFP round. The main goal of this program is to encourage pilot projects that reduce nutrient content in waste streams generated from animal feeding operations.

To apply and for more information, go to www.fppcinc.org.

Farm Pilot Project Coordination, Inc.
Phone: (800) 829-8212
E-mail: info@fppcinc.org
Fax: (813) 222-3298

- Federal Investment Tax Credit (Business Energy Tax Credit), IRS

The Federal Investment Tax Credit is a corporate tax credit for solar PV, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, geothermal electric, fuel cells, solar hybrid lighting, direct use geothermal, and microturbines.

- Solar: Businesses and residents are eligible for a tax credit of 30 percent of the capital costs of a solar PV system. For solar, there is no cap for commercial installations. Credit drops to 10 percent of the capital cost if the system is installed after January 1, 2009.
- Microturbine: Businesses and residents are eligible for a tax credit of 10 percent of the capital costs for microturbines. The maximum microturbine credit is $200 per kW of rated capacity. For microturbines, the credit expires January 1, 2009.

- Fuel cell: Businesses and residents are eligible for a tax credit of 30 percent of the capital costs of a fuel cell system. The credit for fuel cells is capped at $500 per 0.5 kW of capacity. For fuel cells, the credit expires January 1, 2009.
- To apply, fill out IRS Form 3468 (www.irs.gov/pub/irs-pdf/f3468.pdf).

For more information, go to http://dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US02F&State=federal&currentpageid=1&ee=0&re=1 and http://www.seia.org/getpdf.php?iid=21.

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www.irs.gov

- Modified Accelerated Cost Recovery System (MACRS), IRS

Commercial and industrial sectors are eligible for recovering investments in certain property through depreciation deductions.

Microturbine, fuel cell, solar PV, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, solar hybrid lighting, wind, geothermal electric and direct use geothermal properties are eligible.

- Solar power, wind power, fuel cell and microturbine property are eligible for five year accelerated depreciation.
- Fill out IRS Form 4562 (www.irs.gov/pub/irs-pdf/f4562.pdf).

For information on how to estimate accelerated depreciation, go to www.sdenergy.org/uploads/PV-Federal%20Tax%20Credits%20Summary%206-01-04%20FINAL.pdf.

For more information, go to www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US06F&State=Federal&currentpageid=1.

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www.irs.gov

- National Clean Diesel Campaign (NCDC), EPA

The NCDC is an EPA program that works to reduce pollution resulting from existing diesel vehicles and equipment. Fleet owners are encouraged to install pollution-reducing devices on the vehicles and to use cleaner-burning diesel fuel.

For a listing of potential funding resources, go to www.epa.gov/cleandiesel/grantfund.htm.

□ Pollution Prevention (P2) Grants Program, EPA Office of Pollution Prevention and Toxics

The goal of the P2 Grants Program is to assist businesses and industries to better identify environmental strategies and solutions for reducing or eliminating waste at the source. Funds awarded through this grant program support businesses and industries to reduce the release of potentially harmful pollutants across all environmental media: air, water, and land. EPA is interested in supporting projects that reflect comprehensive and coordinated pollution prevention planning and implementation efforts within the state or tribe.

Eligible applicants include the 50 States, the District of Columbia, the U.S. Virgin Islands, the Commonwealth of Puerto Rico, any territory of or possession of the U.S., any agency or instrumentality of a state including state colleges, universities, and Indian Tribes that meet the requirement for treatment in a manner similar to a state in 40 CFR 35.663 (Code of Federal Regulations) and intertribal consortia that meet the requirements in 40 CFR 35.504. Local governments, private universities, private nonprofit organizations, private businesses, and individuals are not eligible for funding.

- Grant recipients must provide at least a 50 percent match of the total allowable project cost by the time of award to be considered eligible to receive funding.
- For purposes of this grant announcement, pollution prevention/source reduction is defined as any practice which:
  - Reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment or disposal;
  - Reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants; and
  - Reduces or eliminates the creation of pollutants through increased efficiency in the use of raw materials, energy, water, or other resources; or protection of natural resources by conservation.
- $4.5 million in total program funding were available for FY 2007.
- P2 Grants is an annual program. Go to the link below to check for RFPs.

For more information, go to www.epa.gov/oppt/p2home/pubs/grants/ppis/ppis.htm.

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□ Public Interest Energy Research (PIER) Program, California Energy Commission (CEC)

The PIER Program supports energy research, development and demonstration (RD&D) projects that will help improve the quality of life in California by bringing environmentally safe, affordable and reliable energy services and products to the marketplace. Applicants need not be a California business.

The PIER Program annually awards up to $62 million to conduct public interest energy research by partnering with RD&D organizations including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Renewable Energy Technologies
- Energy Innovations Small Grant Program
- Energy-Related Environmental Research
- Energy Systems Integration
- Buildings End-Use Energy Efficiency
- Climate Change Program
- Environmentally-Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Natural Gas Research
- Transportation Research

For more information, go to www.energy.ca.gov/pier.

For current solicitations, go to www.energy.ca.gov/contracts/pier.html.

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PIER Program
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□ Renewable Electricity Production Tax Credit (REPC), IRS

This incentive applies to biomass, landfill gas, wind power, hydroelectric, geothermal electric, municipal solid waste, refined coal, and indian coal. First enacted under the Energy Policy Act of 1992, it has subsequently been renewed, most recently by the Tax Relief and Health Care act of 2006 which extends it to December 31, 2008. Commercial and industrial entities may apply for this tax credit.

- Indexed for inflation, wind power currently receives 1.9¢ per kWh produced.
- Indexed for inflation, landfill gas currently receives 1.0¢ per kWh produced for the first 10 years of operation.
- Indexed for inflation, "open-loop biomass" currently receives 1.0¢ per kWh produced for the first 10 years of operation.
  - "Open-loop biomass" is residual biomass that otherwise may be considered "waste" materials, e.g., livestock manure, forestry residues.

- Indexed for inflation, "closed-loop biomass" currently receives 1.9¢ per kWh produced for the first 10 years of operation.
  - "Closed-loop biomass" is biomass that was produced specifically for fuel generation.
- To apply for the credit, a business must complete Form 8835, "Renewable Electricity Production Credit" (www.irs.gov/pub/irs-pdf/f8835.pdf), and Form 3800, "General Business Credit" (www.irs.gov/pub/irs-pdf/f3800.pdf).

For more information, go to http://dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US13F&State=federal&currentpageid=1&ee=1&re=1.

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□ Renewable Energy Systems and Energy Efficiency Improvements Program, USDA

The 2002 Farm Bill established the Renewable Energy Systems and Energy Efficiency Improvements Program under Title IX, Section 9006. This section directs the Secretary of Agriculture to make loans, loan guarantees, and grants to farmers, ranchers and rural small businesses to purchase renewable energy systems and make energy efficiency improvements. Congress provided nearly $23 million to fund the program in each fiscal year from 2003-2006. For FY 2007 there were approximately $11.4 million in funding for competitive grants and $176.5 million in authority for guaranteed loans. Funds are expected to be available in the future.

Applicants may qualify for a grant, a guaranteed loan, or a combination of both.

- Eligible renewable energy projects include systems that generate energy from wind, solar, biomass, or geothermal source or that produce hydrogen derived from biomass or water using a renewable energy source.
- Energy efficiency projects typically involve installing or upgrading equipment that results in a significant reduction in energy use from current operations.
- Eligible applicants are agricultural producers and rural small businesses demonstrating financial need.
- The renewable energy or energy efficiency project must be located in a rural area.
- The project must be for a pre-commercial or commercially available and replicable technology.
- Grant request must not exceed 25 percent of the eligible project costs. Renewable energy grants can range from $2,500 to $500,000. Energy efficiency grants can range from $1,500 to $250,000.
- Loan guarantees can be for up to 50 percent of total eligible project costs. Guarantees can range from $5,000 to $10,000,000 per project.

- Eligible project costs include: Post-application purchase and installation of equipment, except agricultural tillage equipment and vehicles; Post-application construction or project improvements, except residential; Energy audits or assessments; Permit fees; Professional service fees, except for application preparation; Feasibility studies; Business plans; Retrofitting; and Construction of a new facility only when the facility is used for the same purpose, is approximately the same size, and based on the energy audit will provide more energy savings than improving an existing facility. Only costs identified in the energy audit for energy efficiency projects are allowed.

For more information go to www.rurdev.usda.gov/rbs/farmbill/.

To apply, contact your State Office Rural Energy Coordinators:

Arizona
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□ Renewable Energy Production Incentive (REPI), IRS

The REPI provides payments for electricity produced and sold by new qualifying renewable energy generation facilities. This incentive applies to solar PV, wind, geothermal, biomass, landfill gas, livestock methane, ocean technologies, and fuel cells using renewable fuels. The REPI program was created by the Energy Policy Act of 1992 to provide financial incentives for renewable energy electricity produced and sold by qualified renewable energy generation facilities.

Eligible electric production facilities that may be considered to receive REPI payments include not-for-profit electrical cooperatives, public utilities, state governments, commonwealths, territories of the United States, District of Columbia, Indian tribal governments, and political subdivision thereof, and native corporations that sell the facility's electricity.

- Qualifying facilities are eligible for annual incentive payments of 1.5¢ per kWh produced and sold (1993 dollars and indexed for inflation) for the first 10-year period of their operation, subject to the availability of annual appropriations in each federal fiscal year of operation.
- Applicants must meet qualified technology and facility location requirements.

To apply and for more information go to www.eere.energy.gov/repi/.

Christine Carter
DOE
1617 Cole Boulevard
Golden, Colorado 80401
Phone: (303) 275-4755
E-mail: christine.carter@go.doe.gov

Information Specialist - REPI
DOE
Weatherization and Intergovernmental Program
Washington, DC
E-mail: repi@ee.doe.gov

- Renewable Energy Grants and Loans Programs, USDA Rural Development

Under the authority of the Rural Electrification Act of 1936, USDA Electric Programs make direct loans and loan guarantees to electric utilities to serve customers in rural areas.

- High Energy Cost Grants (CFDA 10.859): These grants are available for communities with average home energy costs exceeding 275 percent of the national average. Funds may be used for improving and providing energy generation, transmission and distribution facilities. Grant funds may be used for on-grid and off-grid renewable energy projects, energy efficiency and energy conservation projects serving eligible communities. For more details, go to www.usda.gov/rus/electric/hecgp/overview.htm.
- Treasury Loans: These loans are available for distribution, subtransmission, and renewable generation facilities that provide retail or power supply service needs in rural areas. For more details, go to www.usda.gov/rus/electric/loans.htm.

Karen Larsen
Rural Development Electric Programs
USDA
1400 Independence Avenue, SW Stop 1560, Room 5165-South
Washington, DC 20250-1560
Phone: (202) 720-9545
E-mail: energy.grants@wdc.usda.gov.
Fax: (202) 690-0717

- Sustainable Agriculture Research and Education (SARE) Grants, USDA Cooperative State Research, Education, and Extension Service

The SARE program is part of USDA's Cooperative State Research, Education, and Extension Service, first funded by Congress in 1988. SARE is a competitive grants program providing grants to researchers, agricultural educators, farmers and ranchers, and students in the United States. The SARE program is divided into four regions, with each region announcing its own calls for proposals.

- Research and Education Grants: Ranging from $30,000 to $150,000 or more, these grants fund projects that usually involve scientists, producers, and others in an interdisciplinary approach.
- Professional Development Grants: To spread the knowledge about sustainable concepts and practices, these projects educate Cooperative Extension Service staff and other agriculture professionals.

- Producer Grants: Producers apply for grants that typically run between $1,000 and $15,000 to conduct research, marketing and demonstration projects and to share results with other farmers and ranchers.

For more information on the Western Region, go to http://wsare.usu.edu/.

Western Region SARE
Utah State University
Phone: (435) 797-2257
E-mail: wsare@mendel.usu.edu

□ West Coast Diesel Collaborative Grants, NCDC

The National Clean Diesel Campaign provides monies for regional collaboratives to award as grants for projects that reduce diesel emissions from existing diesel engine operations. States, Federally Recognized Indian Tribes and Tribal Consortia, local governments, international organizations, public and private universities and colleges, hospitals, laboratories, and other public or private nonprofit institutions are eligible to apply. Applicable technologies, fuels, and practices include emissions control technologies, idling reduction strategies, cleaner burning fuels, and alternative and biofuels production, distribution, and use. All projects must demonstrate applications, technologies, methods or approaches that are new, innovative or experimental.

Go to www.epa.gov/region09/funding/cleandiesel.html and www.epa.gov/diesel/grantfund.htm for more information.

Wayne Elson
West Coast Diesel Collaborative Construction Sector Lead
EPA Region 10
1200 Sixth Avenue
Seattle, WA 98101
Phone: (206) 553-1463
E-mail: elson.wayne@epa.gov

9.3 ARIZONA FUNDING

□ Commercial/Industrial Solar & Wind Tax Credit (Corporate)

This tax credit was established by the Arizona legislature in 2006 to stimulate the production and use of solar energy in commercial and industrial applications by subsidizing the initial cost of solar energy devices. It is applicable towards solar PV, wind power, passive solar space heat, solar water heat, solar thermal electric, solar thermal process heat, solar cooling, solar pool heating, and daylighting.

- Businesses are eligible for a tax credit equal to 10 percent of the installed cost of the PV or wind power system.
- Tax credit applies to taxable years from January 1, 2006 through December 31, 2012.
- The maximum credit per taxpayer is $25,000 for any one building in the same year and $50,000 in total credits in any year.

- To qualify for the tax credits, a business must submit an application to the Arizona Department of Commerce. The Department of Commerce may certify tax credits up to a total of $1 million each calendar year.

For more information, go to:

- Arizona Department of Commerce
  www.azcommerce.com/BusAsst/Incentives/Solar+Energy+Tax+Incentives+Program.htm
- Commercial Solar Energy Tax Incentives Program Summary
  www.azcommerce.com/doclib/finance/solar%20program%20summary.pdf
- Commercial Solar Energy Tax Credit Program: Program Guidelines
  www.azcommerce.com/doclib/finance/solar%20guidelines.pdf

Arizona Department of Commerce
1700 W. Washington St., Suite 600
Phoenix, AZ 85007
Phone: (602) 771-1100
www.azcommerce.com

Arizona Department of Revenue
1600 W. Monroe
Phoenix, AZ 85007-2650
Phone: (602) 255-2060
www.azdor.gov

9.4 CALIFORNIA FUNDING

- California Emerging Renewables Program (ERP), California Energy Commission (CEC)

The ERP provides incentives for wind turbines and fuel cells. The ERP is an element of the Renewable Energy Program pursuant to Senate Bill 10381, Senate Bill 1832, Senate Bill 12503, and Senate Bill 107.4.

- Wind power: First 7.5 kW receives $2.50 per watt, then increments between 7.5-kW and 30-kW receives $1.50 per watt. Wind turbines must be rated 50 kW or less.
- Fuel cell: $3.00 per kW. Incentive available for up to 30 kW.

Requirements:

- Must be customer of Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas and Electric (SDG&E), or Southern California Water Company (Bear Valley Electric Service).
- Must use new components that are approved by the California Energy Commission. Find a list of eligible equipment at www.consumerenergycenter.org/erprebate/equipment.html.
- System must have a five-year warranty.
- System must be sized to produce electricity primarily to offset part or all of the customer's needs at the site of installation. The expected production of electricity by the system may not be more than the historical or expected electrical needs of the electricity consumer at the site of installation.
- All systems must be installed with a performance meter.

For more information and to apply, go to www.consumerenergycenter.org/erprebate/program.html.

See the *Emerging Renewables Program Final Guidebook*, Eighth Edition, December 2006, (www.energy.ca.gov/2006publications/CEC-300-2006-001/CEC-300-2006-001-ED8F.PDF) for more details.

California Energy Commission
Emerging Renewables Program
1516 Ninth Street MS-45
Sacramento, CA 95814
Phone: (800) 555-7794 in CA or (916) 654-4058 outside CA
E-mail: renewable@energy.state.ca.us

- California Solar Initiative (CSI), California Public Utilities Commission

The California Solar Initiative is made up of two components. The California Public Utilities Commission (CPUC) will provide over $2 billion in incentives over the next decade for existing residential homes and existing and new business, industrial, non-taxable (government and non-profit) and agricultural properties. The CSI also includes an additional $350 million from the California Energy Commission (CEC) for the New Solar Homes Partnership. Find the *California Solar Initiative Program Handbook* at www.gosolarcalifornia.ca.gov/documents/index.html.

The CSI includes two incentives types (customers can only participate in one):

- Performance Based Incentive (PBI)

  For this incentive type, all customers that install systems greater than 100 kW CEC–AC* will receive a monthly payment based on the actual energy produced, for a period of 5 years. Systems less than 100 kW CEC-AC may opt for PBI. PBI is required for Building Integrated PV (BIPV) Systems. Once the PBI incentive rate has been determined and a confirmed reservation issued, the incentive rate per kWh will remain constant for the 5-year term (Fig. 47). Program Administrators will make monthly payments to applicants based on actual electricity generated in kWh per the monthly reading of the meter after commissioning of the system.

- Expected Performance Base Buydown (EPBB)

  Under this incentive, all systems less than 100 kW will be paid a one-time, up-front incentive based on expected system performance, which considers factors such as equipment ratings, geographic location, tilt, and shading (Fig. 47). Residential and small projects can also choose to opt-in to the PBI payment approach. On January 1, 2008, PBI will apply to

* CEC-AC is California Energy Commission Rated AC output of the PV system that takes into consideration real-world conditions and inverter efficiency.

systems equal to or greater than 50 kW CEC-AC. Starting in 2010, all systems greater than 30 kW will be under the PBI.

		EBPP Payments (per watt)			PBI Payments (per kWh)		
MW Step	Statewide MW in Step	Residential	Commercial	Gov't/ Nonprofit	Residential	Commercial	Gov't/ Nonprofit
1	50	n/a	n/a	n/a	n/a	n/a	n/a
2	70	$ 2.50	$ 2.50	$ 3.25	$ 0.39	$ 0.39	$ 0.50
3	100	$ 2.20	$ 2.20	$ 2.95	$ 0.34	$ 0.34	$ 0.46
4	130	$ 1.90	$ 1.90	$ 2.65	$ 0.26	$ 0.26	$ 0.37
5	160	$ 1.55	$ 1.55	$ 2.30	$ 0.22	$ 0.22	$ 0.32
6	190	$ 1.10	$ 1.10	$ 1.85	$ 0.15	$ 0.15	$ 0.26
7	215	$ 0.65	$ 0.65	$ 1.40	$ 0.09	$ 0.09	$ 0.19
8	250	$ 0.35	$ 0.35	$ 1.10	$ 0.05	$ 0.05	$ 0.15
9	285	$ 0.25	$ 0.25	$ 0.90	$ 0.03	$ 0.03	$ 0.12
10	350	$ 0.20	$ 0.20	$ 0.70	$ 0.03	$ 0.03	$ 0.10

Figure 47 PBI and EPBB incentive amounts by step. Step increases based on participation. Go to www.csi-trigger.com to see current step level. Image courtesy CPUC[275]

Requirements to qualify for PBI or EPBB:

- Must be customer of PG&E, SCE, or SDG&E.
- System equipment and retailers must be certified by CEC. (www.consumerenergycenter.org/erprebate/equipment.html)
- PV systems must be at least 1 kW to be eligible. The maximum limit for an eligible system is 5,000 kW though the incentive can only apply up to 1,000 kW.
- System output (kW) are calculated using CEC-AC standards. See the *CSI Program Handbook*, Section 2.2.5 "System Size" for details (www.gosolarcalifornia.ca.gov/documents/CSI_HANDBOOK.PDF). EPBB applicants go to www.csi-epbb.com/ for the EPBB calculator.
- All existing residential and commercial customers are required to have an energy efficiency audit conducted on their home or building. See Section 2.3 "Energy-Efficiency Requirements" of the *CSI Handbook* for details (www.gosolarcalifornia.ca.gov/documents/CSI_HANDBOOK.PDF).
- All systems must have a minimum 10-year warranty provided both by the manufacturer and installer to protect the purchaser against defective workmanship, system or component breakdown, or degradation in electrical output of more than 15 percent from their originally rated electrical output during the ten-year period. The warranty must cover the solar generating system and provide for no-cost repair or replacement of the system or system components, including any associated labor during the warranty period.
- Meters must have a one-year warranty to protect against defective workmanship, system or component breakdown, or degradation in electrical output of more than 15

percent from their originally rated electrical output during the warranty period. On or before January 1, 2008, the warranty requirements will be increased to a minimum of 5 years for meters, unless the CEC establishes alternate requirements.

- Equipment installed under the CSI program is intended to be in place for the duration of its useful life. Only permanently installed systems are eligible for incentives.
- The Host Customer, or designate, must also submit an application and enter into an interconnection agreement with their local electric utility for connection to the electrical distribution grid. Proof of interconnection and parallel operation is required prior to receiving an incentive payment.
- The CSI program requires accurate solar production meters for all projects that receive CSI program incentives. For systems with a system rating of less than 10 kW, a basic meter with accuracy of ± 5 percent is required. For systems with a system rating of 10 kW and greater, an interval data meter with accuracy of ± 2 percent is required.

When to apply for CSI incentives:

- Select a solar installer
- Determine that the cleanup site is eligible for CSI Incentives
- Apply for and reserve your incentives

  PG&E customers visit: www.pge.com/csi
  SCE customers visit: www.sce.com/rebatesandsavings/CaliforniaSolarInitiative/
  SDG&E customers visit:
  www.sdenergy.org/ContentPage.asp?ContentID=377&SectionID=406&SectionTarget=370
- Install the PV system
- Collect the rebate or payments

For details on the application process, refer to Chapter 4 of the *CSI Handbook* (www.gosolarcalifornia.ca.gov/documents/CSI_HANDBOOK.PDF).

Pacific Gas & Electric
Program Manager, California Solar Initiative Program
Attn: California Solar Initiative
P.O. Box 7265
San Francisco, CA 94120-7265
Phone: Business Customers: 1-800-468-4743; Solar Hotline: 1-415-973-3480
Fax: 415-973-2510
E-mail: solar@pge.com
www.pge.com/solar

San Diego Area: California Center for Sustainable Energy (formerly the San Diego Regional Energy Office)
John Supp, Program Manager
California Center for Sustainable Energy
Attn: CSI Program Manager
8690 Balboa Avenue Suite 100
San Diego, CA 92123

Phone: (858) 244-1177; (866)-SDENERGY
Fax: 858-244-1178
E-mail: csi@energycenter.org
www.energycenter.org

Southern California Edison
California Solar Initiative Administrator
6042A Irwindale Avenue
Irwindale, CA 91702
Phone: (800) 799-4177
Fax: (626) 302-6253
E-mail: greenh@sce.com
www.sce.com/rebatesandsavings/CaliforniaSolarInitiative/

- Carl Moyer Memorial Air Quality Standards Attainment Program (CMP), CARB

CMP is administered by CARB in partnership with local air quality districts throughout the state. CMP funds may only be used to generate surplus emission reductions such as to reduce emissions beyond what is required by applicable standards or regulations, not to be used to comply with any applicable emission standards or regulations. Both public agencies and private entities that own and operate eligible diesel equipment can apply for CMP grant funds. Eligible projects may include the repowering or retrofitting of existing engines and vehicles, as well as the purchase of new low-emission engines or vehicles.

For more information, go to www.arb.ca.gov/msprog/moyer/moyer.htm.

To apply, contact your local air district: www.arb.ca.gov/msprog/moyer/contacts.htm.

California Air Resources Board
Phone: (916) 323-6169

- Energy Efficiency and Renewable Generation Emerging Technologies, Agriculture and Food Industries Loan Program (Loan Program), California Energy Commission

The Loan Program offers 3.2 percent interest loan funds for the purchase of proven cost-effective energy efficient and renewable generation emerging technologies applicable to the agricultural and food processing industries.

Applicable technologies include:

- Food and animal waste bio-energy generation
- Solar PV and solar thermal systems
- Thermal heat pumps
- Electrodialysis membrane systems
- Enterprise energy management systems
- Heating and cooling topping cycle systems
- Ultra-low NO_x controlled energy efficient burners

An energy efficient emerging technology is defined as a technology that is commercially available, is proven through an independent evaluation to reach new efficiency performance benchmarks when compared to current technologies, and has yet to be adopted by no more than 10 percent of the agricultural and food industries in California.

Available Funding

The Loan Program has approximately $3 million available for project financing. The maximum loan amount for any applicant is $500,000 to finance a single project or multiple projects. The minimum loan amount for any applicant is $50,000. Funds are available for the design, purchase and installation of the eligible emerging technology. The interest rate is 3.2 percent. Interest will be calculated as simple interest and the rate will remain fixed during the life of the loan. The maximum repayment term cannot exceed 7 years. Interest accrues starting from the date funds are disbursed to the loan recipient.

Only the following types of facilities are eligible to apply for funding under this program:

- Food and Fiber Processing
- Animal Feeding and Processing
- Breweries, Wineries, Creameries
- Irrigation Districts
- Agricultural Production

Application Process

Securing the loans will require one of the following types of collateral:

- Standby Letter of Credit (a letter of credit is the preferred security)
- Certificate of Deposit (a CD will be considered if applicant is unable to obtain a letter of credit on terms acceptable to the Commission)

Applications are continuously accepted on a first come first served basis as long as funds are available. The program began in April of 2007.

For more information and applications, go to www.energy.ca.gov/process/agriculture/loansolicitation/index.html.

Ricardo Amón
California Energy Commission
Grants and Loans Office
Attn: Emerging Energy Efficient Technologies Loan Demonstration Program
1516 Ninth Street, MS-1
Sacramento, CA 95814-5512
Phone: (916) 654-4019
E-mail: ramon@energy.state.ca.us

- Self Generation Incentive Program (SGIP), California Public Utilities Commission

California's Assembly Bill 970, enacted in September 2000, ordered the establishment of additional energy supply and programs in the state. In March 2001, the California Public Utilities Commission introduced the SGIP. Eligible technologies include wind turbines, gas turbines, internal combustion engines, microturbines, and fuel cells using renewable fuels (Fig. 48). Approximately $500 million was made available for 2003 to 2008.

Incentive Levels	Eligible Technologies	Incentive Offered ($/Watt)	Minimum System Size	Maximum System Size	Maximum Incentive Size
Level 2 Renewable Non-Solar	Wind turbines	$1.50/W	30 kW	5 MW	1 MW
	Renewable fuel cells	$4.50/W			
	Renewable fuel microturbines and small gas turbines	$1.30/W	None		
	Renewable fuel internal combustion engines and large gas turbines	$1.00/W	None		
Level 3 Non-Renewable Non-Solar	Non-Renewable fuel cells	$2.50/W	None	5 MW	1 MW
	Non-Renewable & Waste Gas fuel microturbines and small gas turbines	$0.80/W			
	Non-Renewable & Waste Gas fuel internal combustion engines and large gas turbines	$0.60/W			

Large gas turbines are ≥ 1 MW in capacity. Small gas turbines and microturbines are <1 MW in capacity.

Figure 48 Self-Generation Incentive Program incentive rates.[276]

Minimum Requirements:

- Must be customer of Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas and Electric (SDG&E), or Southern California Gas Company.
- May not use more than 25 percent fossil fuel annually.
- All self-generation equipment must be connected to the electricity grid and installed on the customer's side of the utility meter.
- Self-generation equipment must be new and permanent; demonstration units are not eligible.
- A portion of the facility's electric load must be offset by the equipment.

The *2007 Self-Generation Incentive Program Handbook* is available at www.socalgas.com/business/selfgen/docs2007/2007_SGIP_Handook.pdf.

For more information, go to www.cpuc.ca.gov/PUC/energy/051005_sgip.htm and contact local utilities to apply.

Pacific Gas & Electric Co.
Self-Generation Incentive Program
P.O. Box 770000
Mail Code B29R
San Francisco, CA 94177
Phone: (415) 973-6436
Fax: (415) 973-2510
E-mail: selfgen@pge.com
http://www.pge.com/selfgen/

San Diego Regional Energy Office
(Administrator for San Diego Gas & Electric)
401 B Street, Suite 800
San Diego, CA 92101
Phone: (619) 595-5630
Fax: (619) 595-5305
E-mail: selfgen@sdenergy.org
http://www.sdenergy.org/ContentPage.asp?ContentID=35&SectionID=24

Southern California Edison
Program Manager, Self Generation Incentive Program
2131 Walnut Grove Avenue
3rd floor, MS B10
Rosemead, CA 91770
Phone: (800) 736-4777

Fax: (626) 302-6253
E-mail: greenh@sce.com
www.sce.com/RebatesandSavings/SelfGenerationIncentiveProgram/

Southern California Gas Company
Self-Generation Incentive Program Administrator
555 West Fifth Street, GT15F4
Los Angeles, CA 90013
Phone: (800) GAS-2000
Fax: (213) 244-8384
E-mail: selfgeneration@socalgas.com
www.socalgas.com/business/selfgen

9.5 HAWAII FUNDING

- Hawaii Renewable Energy Tax Credits OR Capital Goods Excise Tax

These two incentives are tax credits and are essentially the same and one may not be used in conjunction with the other. Businesses and residents are eligible to apply. Eligible technologies include solar PV, wind power, solar water heat, solar space heat, and solar thermal electric.

For PV systems, the maximum allowable credits are as follows:

- Commercial property is eligible for a credit of 35 percent of the initial cost or $500,000, whichever is less.
- Single-family residential property is eligible for a credit of 35 percent of the initial cost or $5,000, whichever is less.
- Multi-family residential property is eligible for a credit of 35 percent of the initial cost or $350 per housing-unit, whichever is less.

For wind power systems, the maximum allowable credits are as follows:

- Commercial property is eligible for a credit of 20 percent of the actual cost or $500,000, whichever is less.
- Single-family residential property is eligible for a credit of 20 percent of the actual cost or $1,500, whichever is less.
- Multi-family residential property is eligible for a credit of 20 percent of the actual cost or $200 per unit, whichever is less.

For more information, go to www.hawaii.gov/dbedt/info/energy/renewable/solar.

Hawaii Department of Taxation
Taxpayer Services Branch
P.O. Box 259
Honolulu, HI 96809
Phone: (808) 587-4242
www.state.hi.us/tax

9.6 NEVADA FUNDING

□ Renewable Energy Producers Property Tax Abatement

This incentive is a tax abatement for new or expanded commercial businesses. This incentive is applicable for solar PV, wind, solar thermal electric, landfill gas, biomass, municipal solid waste, and anaerobic digesters. Expires June 30, 2009.

- The incentive is a 50 percent property tax abatement for 10 years for real and personal property used to generate electricity from renewable energy resources or for a facility for the production of an energy storage device.
- The generation facility must have a capacity of at least 10 kW and use biomass, solar, or wind resources as its primary source of energy.
- The business must also meet capital expenditure, employee compensation, and other requirements to be eligible for the incentive.

For more information, go to:

- Nevada Commission on Economic Development Tax Abatement Factsheet
www.expand2nevada.com/whatwedo/pdfs/08renewableenergy.pdf
- Database of State Incentives for Renewables and Efficiency by North Carolina State University
www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=NV01F&state=NV&CurrentPageID=1&RE=1&EE=0

To apply, contact:

Susan Combs
Nevada Commission on Economic Development
108 E. Proctor Street
Carson City, NV 89701
Phone: (775) 687-4325
Phone 2: (800) 336-1600
Fax: (775) 687-4450
E-mail: scombs@bizopp.state.nv.us

□ Renewable Energy Systems Property Tax Exemption

This incentive is a property tax exemption that applies to solar PV, passive solar space heat, solar water heat, and solar space heat. Commercial and industrial sectors may apply. This exemption was enacted in 1997 and runs until January 2009. The renewable energy property tax exemption cannot be claimed if another state tax abatement or exemption is claimed by the same building.

- There is a 50 percent tax abatement for qualifying systems for 10 years.
- The generation facility must have a capacity of at least 10 kW.

For more information, go to http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=NV02F&state=NV&CurrentPageID=1&RE=1&EE=0.

Information Specialist – Dept. of Taxation
NV Department of Taxation
1550 E. College Parkway, Suite 115
Carson City, NV 89706
Phone: (775) 684-2000
Fax: (775) 684-2020

- Solar Generations PV Rebate Program, Sierra Pacific Power and Nevada Power

Solar Generations is a program administered by Sierra Pacific Power Company and Nevada Power Company to help these utilities meet their renewable portfolio standards. It provides a rebate on PV systems for businesses, residences, schools, local government, state government, and other public buildings serviced by Sierra Pacific Power or Nevada Power. The utilities will own the renewable energy credits from the electricity produced by the customer's PV system (See Section 2.5 page 11).

Incentive amounts are:

- Schools: $5 per watt AC (up to a total capacity of 570 kW for all school projects).
- Public Buildings: $5 per watt AC (up to a total capacity of 570 kW for all public building projects).
- Residences/Small Businesses: $3 per watt AC (up to a total capacity of 760 kW each of the remaining program years).

Eligibility requirements:

- Rebate applies to a maximum of 5 kW of rated AC output for residential systems and 30 kW of rated AC output for small businesses, schools, or public buildings.
- The equipment installed must be on the list of certified PV modules and inverters provided by the California Energy Commission (CEC) Program found at www.consumerenergycenter.org/erprebate/equipment.html.
- A Nevada-licensed electrical contractor must install the system. The State of Nevada requires PV system installers in Nevada to hold an annually renewable PV license requirement. A list of contractors who have participated in Solar Generations training is available at www.solargenerations.com/contractors.html though this does not guarantee that they are properly licensed.
- Program participants must also sign a net metering agreement with the utility.

For more information, go to www.solargenerations.com.

SolarGenerations Rebate Program
6100 Neil Road
Reno, NV 89511
Phone: (866) 786-3823
E-mail: info@SolarGenerations.com

CHAPTER 10: TOOLS

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This chapter includes tools related to energy efficiency, purchasing cleaner energy, renewable energy, and cleaner diesel. Energy efficiency tools include calculators to assess efficiency of pumps, potential federal technical assistance resources, and a toolkit on greener cleanups. Tools to assist in purchasing cleaner energy include resources of further information on how to buy green energy, where to find clean energy programs, and a resource on clean energy technical assistance. General renewable energy tools include calculators to estimate emissions and emissions reductions, software to help model the energy outputs and benefits of a renewable energy system, map data depicting renewable energy resources in the state, potential technical assistance resources, and resources on checking a renewable energy contractor’s licenses. There is a tools section for each of the renewable energy technologies detailed in this guide with calculators and models, surveying equipment, sources of further information and potential technical assistance resources. The clean diesel tools section includes calculators to help quantify emissions and emissions reductions, sources of further information, and potential technical assistance resources for cleaner diesel fuels, practices, and technologies.

10.1 ENERGY EFFICIENCY CALCULATORS, TECHNICAL ASSISTANCE RESOURCES, AND INFORMATIONAL RESOURCES

- Agricultural Pumping Efficiency Program (California Public Utilities Commission (CPUC) and California State University (CSU) Fresno): The Agricultural Pumping Efficiency Program is a local resource for California. It is comprised of a partnership between the CPUC and CSU at Fresno's Center for Irrigation Technology. PG&E and SCE customers are eligible. This program provides free pump efficiency tests, educational seminars, and incentives for pump retrofits. Check with your local utility to see if similar programs are available for your cleanup site. www.pumpefficiency.org/

  For the Pumping Cost Analysis Calculator for electric pumps, go to http://www.pumpefficiency.org/Pumptesting/costanalysis.asp.

  Agricultural Pumping Efficiency Program
  Center for Irrigation Technology

6014 North Cedar Ave.
Fresno, CA 93710
Phone: (800) 845-603

- Federal Energy Management Program (FEMP) (EERE): FEMP is a potential resource to help improve energy efficiency and implement renewable energy projects at your site. FEMP works to reduce costs and environmental impacts of the federal government by advancing energy efficiency and water conservation, promoting the use of distributed and renewable energy, and improving utility management decisions at federal sites. FEMP helps federal energy managers identify, design, and implement new construction and facility improvement projects. This service may be applicable for fund-lead sites. www1.eere.energy.gov/femp/

  FEMP Help Desk
  1000 Independence Ave., SW
  Washington, DC 20585-0121
  Phone: (202) 586-5772
  www1.eere.energy.gov/femp/about/contacts.html

- Greener Practices for Business, Site Development and Site Cleanups: A Toolkit (Minnesota Pollution Control Agency): Use this online toolkit of greener cleanup options, a decision tree, and success stories, to determine how to reduce the environmental footprint from remediation activities. www.pca.state.mn.us/programs/p2-s/toolkit/index.html

- Pumping System Assessment Tool (EERE): The Pumping System Assessment Tool is an online calculator that helps industrial users assess the efficiency of pumping system operations. www1.eere.energy.gov/industry/bestpractices/software.html#psat

- Technical Assistance Project (TAP) for State and Local Officials (EERE): TAP is available to provide state and local officials with quick, short-term access to experts at DOE national laboratories for assistance with their renewable energy and energy efficiency policies and programs. TAP projects are available on a first come, first served basis. Project budgets are limited to $5,000 in staff time and travel. Typically, this can provide a few days of on-site assistance or a week's worth of analysis and consultations via phone and e-mail. www.eere.energy.gov/wip/tap.cfm

  To apply, go to www.eere.energy.gov/wip/how_to_apply.cfm.

  Julie Riel
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  Golden, Colorado
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10.2 PURCHASING CLEAN ENERGY INFORMATIONAL RESOURCES

- EERE Green Power Network: Find state-by-state clean energy purchasing options. www.eere.energy.gov/greenpower/buying/buying_power.shtml

- *The Guide to Purchasing Green Power* (DOE, EPA, World Resources Institute, and Green-e, September 2004): Document detailing steps to purchasing clean energy. www.epa.gov/greenpower/buygp/guide.htm
- *Green Power Marketing in the United States: A Status Report* (NREL March 2003): Document detailing the status of green power marketing in the U.S. www.nrel.gov/docs/fy04osti/35119.pdf
- EPA Green Power Partnership: The EPA Green Power Partnership is a program that encourages U.S. organizations to voluntarily purchase green power as a way to reduce the risk of climate change and the environmental impacts associated with conventional electricity use. This program can assist in navigating the complexities of making a green power purchase. The Green Power Partnership is also available to help identify green power products. To find state-by-state green power products, go to http://www.epa.gov/greenpower/pubs/gplocator.htm.

  www.epa.gov/greenpower/
  James Critchfield
  EPA HQ
  Green Power Partnership
  Phone: (202) 343-9442
  E-mail: critchfield.james@epa.gov

10.3 GENERAL RENEWABLE ENERGY ECONOMIC CALCULATIONS

There are many different ways to look at the economic benefits of installing a renewable energy system. A few methods of analyzing the economics are: (1) rate of return, (2) payback time, and (3) total lifecycle payback. An explanation of these analyses follows using solar PV as an example.

Simple Calculation of Monthly Electricity Bill Savings

The simple calculation in Box 8 estimates electricity bill savings from your site's renewable energy system. Enter the proposed rated power output of the system and the average kWh production each month per rated kW. Using solar PV as an example, 135-150 kWh per month is the general estimate of monthly energy production from a 1-kW system in Region 9 states. Look on your electricity bill for your cost of electricity per kWh. This simple calculation does not take into account that electricity prices are steadily increasing.

Box 8 Monthly Electricity Bill Savings
$$B = S * O * U$$
B = Monthly Electricity Bill Savings ($)
S = Rated Power Output (kW)
O = Average Energy Output (kWh per kW per month);
U = Utility price per kWh ($)

Simple Payback Time[277]

Simple payback time is defined as the time it takes for a renewable energy system to save enough money to pay for itself. This simplified calculation (Box 9) usually only takes into consideration the capital cost of the system and monetary savings from a reduced or eliminated energy bill and does not include operation and maintenance costs. In this model, reduced pollution levels and other non-monetary valued benefits are also not included. Another shortfall of simple payback time is that it does not account for the savings accrued after the payback time. This equation may overestimate the payback time since energy prices are expected to continue to increase.

Box 9 Simple Payback Time
PB = C ÷ B
PB = Payback Time (years) C = Capital Cost ($) B = Annual Electricity Bill Savings ($ per year)

Total Lifecycle Payback[278]

The total lifecycle payback accounts for savings gained after the payback time until the end of the useful life of a renewable energy system (Box 10). Solar PV systems usually last 25-30 years, resulting in savings 2-3 times greater than the initial capital cost. The drawback of this calculation is that it does not reflect the time value of money (having a dollar today is worth more than having a dollar in the future).

Box 10 Total Lifecycle Payback
R = B ÷ C ∗ Y
R = Total Lifecycle Payback Ratio B = Annual Electricity Bill Savings ($ per year) C = Capital Cost ($) Y = Years of operation (years)

10.4 GENERAL RENEWABLE ENERGY CALCULATORS, TECHNICAL ASSISTANCE, INFORMATIONAL RESOURCES AND CONTRACTOR LICENSING INFORMATION

- EPA's Power Profiler: Use this online calculator to determine the emissions emitted from electricity use. It can also be used to determine the pollution avoidance from a renewable energy system. Estimate CO_2, NO_x, and SO_2 emissions avoidance from using renewable energy rather than conventional electricity. To calculate pollutants avoided, enter the estimated amount of renewable energy produced by your renewable energy system into the Profiler instead of entering total electricity consumed. www.epa.gov/cleanenergy/powerprofiler.htm
- Federal Energy Management Program (FEMP) (EERE): FEMP is a potential resource to help improve energy efficiency and implement renewable energy projects at your site. FEMP works to reduce costs and environmental impacts of the federal government by advancing energy efficiency and water conservation, promoting the use of distributed and renewable energy, and improving utility management decisions at federal sites. FEMP helps federal energy managers identify, design, and implement new construction and facility improvement projects. This service may be applicable for fund-lead sites. www1.eere.energy.gov/femp/

FEMP Help Desk
1000 Independence Ave., SW
Washington, DC 20585-0121
Phone: (202) 586-5772
www1.eere.energy.gov/femp/about/contacts.html

- Greenhouse Gas Equivalencies Calculator (EPA): Translate tons of CO_2 and other pollutants into terms that are easier to conceptualize such as number of passenger cars driven, number of seedlings planted, and number of homes powered for a year. www.epa.gov/cleanenergy/energy-resources/calculator.html

- *The Guide to Purchasing Green Power* (DOE, EPA, World Resources Institute, and Green-e, September 2004): Document detailing steps to purchasing clean energy including developing a renewable energy project. www.epa.gov/greenpower/buygp/guide.htm

- HOMER (NREL): Optimization software model to analyze the technical and economic feasibility of distributed power including solar PV, wind power, microturbine, fuel cell, and generators. https://analysis.nrel.gov/homer/

- *Renewable Energy Atlas of the West:* Maps of solar, wind, geothermal and biomass resources created by the Western Resource Advocates, Northwest Sustainable Energy for Economic Development, GreenInfo Network, and Integral GIS, Inc. that can help assess renewable energy potential in the area surrounding a cleanup site. www.energyatlas.org

  Arizona: www.energyatlas.org/PDFs/atlas_state_AZ.pdf
  California: www.energyatlas.org/PDFs/atlas_state_CA.pdf
  Hawaii: not yet available
  Nevada: www.energyatlas.org/PDFs/atlas_state_NV.pdf

- RETScreen International (Natural Resources Canada): This website provides green energy analysis tools developed by Natural Resources Canada in partnership with international organizations such as the United Nations Environmental Programme, NASA, and the World Bank. This MS Excel-based program requires detailed inputs of renewable energy equipment data. This tool can be used for solar, wind, and biomass renewable energy projects. www.retscreen.net

- Technical Assistance Project (TAP) for State and Local Officials (EERE): TAP is available to provide state and local officials with quick, short-term access to experts at DOE national laboratories for assistance with their renewable energy and energy efficiency policies and programs. TAP projects are available on a first come, first served basis. Project budgets are limited to $5,000 in staff time and travel. Typically, this can provide a few days of on-site assistance or a week's worth of analysis and consultations via phone and e-mail. www.eere.energy.gov/wip/tap.cfm

  To apply, go to www.eere.energy.gov/wip/how_to_apply.cfm.

  Julie Riel
  DOE Golden Field Office
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Renewable Energy Contractors' Licenses

Below are websites that will help you to determine whether a prospective contractor is licensed in that state.

- Contractor's License Reference Site: www.contractors-license.org/
- North American Board of Certified Energy Practitioners: www.nabcep.org
- Arizona Registrar of Contractors: www.rc.state.az.us/
- California Contractors State License Board: www.cslb.ca.gov
- Hawaii Department of Commerce: http://hbe.ehawaii.gov/cogs/search.html
- Nevada State Contractors Board: www.nvcontractorsboard.com

10.5 SOLAR POWER TOOLS

Solar Power Calculators

- My Solar Estimator (FindSolar.com): Findsolar.com is created through a partnership among solar professional organizations and DOE. This site provides information on solar incentives, a listing of qualified solar professionals, and a user-friendly PV sizing and economic analysis tool called "My Solar Estimator." This tool outputs solar availability, size of system (kW), space requirements, costs, rebates, loan considerations, savings and benefits including increased property value, return on investment, break even point, and monthly energy bill savings. www.findsolar.com
- PV Watts (Renewable Resource Data Center): PV Watts is a tool hosted by the Renewable Resource Data Center which is supported by the National Center for Photovoltaics and managed by EERE. Use PV Watts to estimate the energy output of your PV system and energy bill savings. www.pvwatts.org
- Clean Power Estimator (Clean Power Research): Clean Power Research provides consulting and software that evaluates the economics of clean energy investments. Use the Clean Power Estimator to estimate the energy output, emissions reductions, and financial benefits of a grid-connected PV system. www.consumerenergycenter.org/renewables/estimator/index.html
- Economic Analysis Tool (OnGrid Solar): OnGrid Solar is a private company that provides financial payback analysis for solar PV installations. Visit the site for a free demo of the Excel tool. Subscription starts at $100 per month. www.ongrid.net

Solar Power Surveying Equipment

- Solar Pathfinder: This device can be used to evaluate annual sun/shading data and is useful for siting a PV system. Its polished transparent dome reflects surrounding buildings, trees, and other obstructions that create shadows (Fig. 49). Included in the kit are "Sunpath Diagrams," which show the sun's average path through the sky specific to your site. The device helps to determine year-round shadows made by surrounding obstructions. As of the writing of this guide, one Pathfinder set costs $259. www.solarpathfinder.com

  

  Figure 49 Solar Pathfinder. Image courtesy Solar Pathfinder[279]

  The Pacific Energy Center, run by PG&E, lends Solar Pathfinders and other surveying tools free of charge to customers working on energy efficiency and renewable energy projects in California. Tools may be loaned for about 2-4 weeks. http://www.pge.com/mybusiness/edusafety/training/pec/toolbox/tll/.

  For other states and territories, check your local utility for similar services.

Solar Power Informational Resources

- *A Consumer's Guide: Get Your Power from the Sun* (EERE, December 2003): A EERE document written for residents who are interested in installing a PV system for their homes. www.nrel.gov/docs/fy04osti/35297.pdf
- EERE Solar PV Website: Website with technology information on solar PV. www1.eere.energy.gov/solar/photovoltaics.html

10.6 WIND POWER TOOLS

Wind Power Calculators

- Wind Energy Payback Period Workbook (EERE): Use this tool to estimate the payback period for your wind power system. www.eere.energy.gov/windandhydro/windpoweringamerica/filter_detail.asp?itemid=1415
- Wind Speed Calculator (Danish Wind Industry Association): Input a known wind speed at a certain height and this calculator outputs estimated wind speeds at other heights. Enter wind speeds in meters per second. This calculator also takes into account variation in terrain which would affect wind speed estimates. www.windpower.org/en/tour/wres/calculat.htm

Wind Surveying Equipment

- Pacific Energy Center (PG&E): The Pacific Energy Center, run by PG&E, lends anemometers and other surveying tools free of charge to customers working on energy efficiency and renewable energy projects in California. Tools may be loaned for about 2-4 weeks. http://www.pge.com/mybusiness/edusafety/training/pec/toolbox/tll/.

For other states and territories, check your local utility for similar services.

Wind Power Technical Support

- California Wind Energy Collaborative (California Energy Commission and University of California at Davis): The California Wind Energy Collaborative is a partnership between the University of California at Davis and the California Energy Commission that supports the development of wind power in California. They provide short training courses for the general public that provides practical information on selecting, installing, and owning a wind turbine. http://cwec.ucdavis.edu/

California Wind Energy Collaborative
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Wind Power Informational Resources

- American Wind Energy Association (AWEA): This website provides information on installers/contractors, state-specific wind power rules, interconnection issues, and wind power incentives (www.awea.org/smallwind/states.html). Find general information on planning a wind project using the AWEA “Small Wind Toolbox” (www.awea.org/smallwind/toolbox). www.awea.org
- British Wind Energy Association Briefing Sheet: Wind turbine technology factsheet. www.bwea.com/pdf/briefings/technology05_small.pdf
- Danish Wind Industry Association: More information on how wind turbines work and wind turbine technology. http://www.windpower.org/en/core.htm
- *Permitting Small Wind Turbines: A Handbook* (American Wind Energy Association): Guide on permitting information for wind turbines. www.awea.org/smallwind/documents/permitting.pdf
- *Small Wind Electric Systems: A U.S. Consumer’s Guide* (EERE, March 2005): An EERE document written mainly for residents who are interested in installing a wind turbine. www.eere.energy.gov/windandhydro/windpoweringamerica/pdfs/small_wind/small_wind_guide.pdf
- *Small Wind Electric Systems: An Arizona Consumer's Guide* (EERE, March 2005): An EERE document written mainly for residents who are interested in installing a wind turbine with information specific to Arizona. www.eere.energy.gov/windandhydro/windpoweringamerica/pdfs/small_wind/small_wind_az.pdf

- EERE Wind Power Website: Information on wind power technology. www1.eere.energy.gov/windandhydro/wind_technologies.html
- NREL Wind Power Website: Information on wind power technology. www.nrel.gov/wind/
- Wind Energy Manual (Iowa Energy Center, 2006): Details on wind power history, technology, and considerations. www.energy.iastate.edu/Renewable/wind/wem-index.htm

10.7 LANDFILL GAS-TO-ENERGY TOOLS

LFGE Calculators

- LFGE Benefits Calculator (LMOP): The LFGE Benefits Calculator can be used to estimate direct, avoided, and total GHG reductions, as well as environmental and energy benefits from a landfill gas-to-energy project. www.epa.gov/landfill/res/calc.htm
- LFGE Potential Project Locator Tool (LMOP): This LMOP tool can help developers determine potential LFGE project sites within a 20-25 mile radius of a particular address. Contact LMOP for assistance. www.epa.gov/lmop/contact/index.htm
- Landfill Gas Emissions Model (LandGEM) (EPA Technology Transfer Network): This model can be used to estimate total LFG and methane generation, as well as emissions of CO_2, NMOCs, and other air pollutants from MSW landfills. It is not intended to characterize emissions from co-disposal landfills. www.epa.gov/ttncatc1/products.html#software
- Landfill Gas Energy Cost Model (EPA, LMOP): Use this tool to estimate the economic feasibility of your MSW LFGE project. http://www.epa.gov/lmop/res/#5

LFGE Informational Resources

- *A Landfill Gas to Energy Project Development Handbook* (EPA LMOP, September 1996): This LMOP handbook includes information on the major aspects of LFG project development, including economic analysis, financing, choosing project partners, environmental permitting, and contracting for services. http://epa.gov/lmop/res/pdf/handbook.pdf

  See *Appendix A: Calculations of Landfill Gas Energy Recovery Project Costs* for an overview of costs. Though the cost estimates are outdated, it may be useful to better understand the services and equipment that must be included and their relative costs. www.epa.gov/lmop/res/pdf/hbookapp.pdf
- *Guidance for Evaluating Landfill Gas Emissions From Closed or Abandoned Facilities* (EPA, September 2005): Use this guidance document for procedures on how to evaluate emissions from co-disposal landfills. www.epa.gov/nrmrl/pubs/600r05123/600r05123.pdf
- *Landfill Gas-To-Energy Potential in California* (California Energy Commission, September 2002): Document that provides information on landfills in California, their potential for generating electricity, applicable technologies, and information on current LFGE projects in California. www.energy.ca.gov/reports/2002-09-09_500-02-041V1.PDF

- *Economic and Financial Aspects of Landfill Gas to Energy Project Development in California* (California Energy Commission, April 2002): Provides general information on LFGE technology and summarizes existing LFGE projects in California. www.energy.ca.gov/pier/final_project_reports/500-02-041v1.html

LFGE Technical Resources

- Landfill Methane Outreach Program, (EPA): The Landfill Methane Outreach Program (LMOP) is an EPA assistance and partnership program that promotes the use of landfill gas as a renewable energy source. 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.

  www.epa.gov/lmop

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

- Methane to Markets Partnership: The Methane to Markets Partnership is a voluntary, non-binding framework for international cooperation to advance the recovery and use of methane as a valuable clean energy source. www.methanetomarkets.org

10.8 ANAEROBIC DIGESTION TOOLS

Anaerobic Digestion Calculators

- Biomass Cost of Energy Calculator (California Biomass Collaborative): Use this calculator to estimate the cost of energy generated from an anaerobic digester. Requires input of detailed technical, financial, and economic assumptions. http://faculty.engineering.ucdavis.edu/jenkins/CBC/Calculator/index.html
- FarmWare (AgStar): Decision support software package that can be used to conduct pre-feasibility assessments for swine and dairy manure digesters. www.epa.gov/agstar/resources/handbook.html
- Financial Analysis Model (New York Agriculture Innovation Center): This spreadsheet model is useful for potential manure digester projects. It estimates financial projections for implementing anaerobic digestion, cogeneration, solids separation, composting, and liquid manure spreading for a farm. Requires detailed inputs including capital costs, depreciation terms, projected construction schedule, and operating costs such as labor hours, fuel use, and insurance costs. This model can be used after initial consultation with vendors. http://hive.bee.cornell.edu/extension/manure/FinancialAnalysis.htm

Anaerobic Digestion Informational Resources

- *Agricultural Biogas Casebook Update 2004,*(Resource Strategies, Inc.): Collection of case studies of digesters in the Great Lakes region. www.rs-inc.com/downloads/Experiences_with_Agricultural_Biogas_Systems-2004_Update.pdf
- Cornell University Anaerobic Digester Website: Technical papers and case studies on anaerobic digesters. www.manuremanagement.cornell.edu/HTMLs/AnaerobicDigestion.htm
- Minnesota Department of Agriculture Anaerobic Digester Web Page: Collection of anaerobic digester studies. www.mda.state.mn.us/renewable/waste/digester-refs.htm
- Penn State University Anaerobic Digester Website: General information on digester technologies, digester safety, case studies, and vendors. www.biogas.psu.edu/anaerobicdigestion.html
- EERE Anaerobic Digester Web Pages: DOE website providing basic information on digesters. www.eere.energy.gov/consumer/your_workplace/farms_ranches/index.cfm/mytopic=30002

Anaerobic Digestion Technical Resources

- AgStar Program: The AgSTAR Program is a voluntary effort jointly sponsored by the EPA, the USDA, and DOE. The program encourages the use of biogas capture and utilization at animal feeding operations that manage manures as liquids and slurries. www.epa.gov/agstar

  AgStar Handbook This handbook is for livestock producers, developers, investors, and others in the agricultural and energy industry that may consider biogas technology as a livestock manure management option. www.epa.gov/agstar/resources/handbook.html

  Managing Manure with Biogas Recovery Systems Improved Performance at Competitive Costs This document provides a general overview on anaerobic digesters. www.epa.gov/agstar/pdf/manage.pdf
- Methane to Markets Partnership: Methane to Markets is a voluntary partnership among international corporations and organizations to advance the recovery and use of methane as a valuable clean energy source. www.methanetomarkets.org

10.9 BIOMASS GASIFIER TOOLS

The following is a list of state-specific information and biomass energy organizations that may be able to provide assistance. Also provided are potential consulting resources that may be able to help to plan a gasifier project.

Biomass Gasifier Informational Resources

- *Analysis of Hawaii Biomass Energy Resources for Distributed Energy Applications* (University of Hawaii at Manoa for the State of Hawaii, December 2002): Research paper studying energy content and chemical composition of different biomass resources available in Hawaii. www.hawaii.gov/dbedt/info/energy/publications/biomass-der.pdf

- “Arizona Biomass Energy Opportunities” (Prepared by TSS Consultants for Greater Flagstaff Forests Partnership, March 2004): Report discussing benefits of using biomass waste from Arizona forest management practices for energy production. www.cc.state.az.us/divisions/utilities/electric/EPS-TSSC.pdf
- Bioenergy Feedstock Information Network: Database of biomass-to-energy documents from the DOE Oak Ridge National Laboratory, DOE Idaho National Laboratory, NREL, and other research organizations. http://bioenergy.ornl.gov/main.aspx
- “Biomass Energy Project Guide” (Oregon Department of Energy): List of steps to plan and implement a gasification project. www.oregon.gov/ENERGY/RENEW/Biomass/guide.shtml
- California Biomass Collaborative: Collaboration of government, industry, educational institutions supporting the growth of biomass energy administered by the University of California at Davis. http://biomass.ucdavis.edu/
- California Biomass Energy Alliance: Association of biomass fueled power plants in California. www.calbiomass.org/
- International Energy Agency (IEA) Bioenergy: IEA Bioenergy is an organization set up in 1978 by the IEA with the aim of improving cooperation and information exchange between countries that have national programs in bioenergy research, development and deployment. Go to their website for technical documents related to gasifiers. www.ieabioenergy.com/

  IEA Bioenergy’s Task 33 has the goal of promoting biomass gasification. It is being conducted by experts from Austria, Canada, Denmark, European Commission, Finland, Germany, Italy, The Netherlands, New Zealand, Sweden, Switzerland, and the U.S. www.gastechnology.org/webroot/app/xn/xd.aspx?it=enweb&xd=iea/homepage.xml
- www.TarWeb.net: Information on tars and other contaminants in gasifier-produced syngas.
- Gasification Technologies Council: Organization of gasifier companies that focus mainly on fossil fuel gasification. Find information on gasification technology. www.gasification.org
- Intelligent Energy for Europe Programme Gasification Guide: "Guideline for Safe and Eco-friendly Biomass Gasification" project supported by the Intelligent Energy for Europe Programme. The document is not yet completed but check the website for updates. www.gasification-guide.eu/

Potential Biomass Gasifier Technical Resources

- Arizona Department of Commerce Energy Programs: www.azcommerce.com/Energy/
- Biomass Energy Resource Center: The Biomass Energy Resource Center is a non-profit organization that works on projects around the country to install systems that use biomass, focusing on woody biomass, to produce heat and/or electricity. They have partnered with schools, communities, colleges, businesses, utilities, and government agencies. Services include:
  - Providing information for potential projects;

- Carrying out or coordinating project-related pre-feasibility studies, feasibility studies, and other reports;
- Carrying out, coordinating, or consulting on the development of biomass energy projects;
- Managing the operations of biomass energy projects; and
- Conducting assessments of working biomass systems.

www.biomasscenter.org

Biomass Energy Resource Center
Montpelier, VT 05601
Phone: (802) 223-7770
E-mail: contacts@biomasscenter.org

- Hawaii Natural Energy Institute (University of Hawaii at Manoa): www.hnei.hawaii.edu/
- Nevada Biomass Working Group (Office of the Governor, Nevada State Office of Energy): http://energy.state.nv.us/renewable/biomass.htm
- Nevada Renewable Energy & Energy Conservation Task Force: www.nevadarenewables.org/?section=biomass
- Renewable Energy Center (University of Nevada at Reno): www.unr.edu/geothermal/UNRREC.htm
- Western Governors' Association Western Regional Biomass Energy Program: www.westgov.org/wga/initiatives/biomass/index.htm

10.10 CLEAN DIESEL TOOLS

Clean Diesel Calculators

- EPA Modeling and Inventories: Go to www.epa.gov/otaq/models.htm for a list of EPA models to inventory emissions across a city, county, or state.
- The Quantifier (EPA): Calculate diesel emissions from your site and the reductions from using cleaner and alternative fuels, retrofits, and engine upgrades for both on-road and off-road engines using this EPA online tool. Emissions output units are in tons. http://cfpub.epa.gov/quantifier/
- Biodiesel Emissions Reduction Calculator (OTAQ): Estimate the percent emissions reductions from different blends of biodiesel with this OTAQ MS Excel calculator. Follow the "biodiesel reduction spreadsheet" link found at www.epa.gov/otaq/retrofit/techlist-biodiesel.htm.
- National Biodiesel Board Emissions Calculator: Enter the amount of biodiesel used to calculate emissions reductions in terms of percentage and pounds of pollutant. www.biodiesel.org/(X(1)S(ux4dpq55txmx5rjnj25h1k55))/tools/calculator/default.aspx?AspxAutoDetectCookieSupport=1

- Biodiesel Comprehensive Calculator (BioFleet): Estimate quantified emissions reductions from using biodiesel with the BioFleet calculator. BioFleet is a biodiesel market development program sponsored by the Canadian government. Note that input and output values are in metric units. http://biofleet.net/index.php?option=com_wrapper&Itemid=58

- Construction Mitigation Calculator (Sacramento Metropolitan Air Quality Management District): The purpose of this MS Excel tool is to calculate emissions from construction activities to see if the levels are below required thresholds. This tool can be used to estimate total PM and NO_x emissions for a cleanup project. www.airquality.org/ceqa/index.shtml#construction

- Idle Reduction Savings Calculator (Argonne National Laboratory): While this tool was developed with a focus on on-road vehicles, it can provide approximate values for emissions savings from idle reduction of off-road vehicles. Follow the link in the right side navigation bar. www.transportation.anl.gov/research/technology_analysis/idling.html

Clean Diesel Informational and Technical Assistance Resources

- Alternative Fuel Station Locater Website (EERE): Visit this website to find a biodiesel, natural gas, or ethanol fueling station. www.eere.energy.gov/afdc/infrastructure/locator.html

- Diesel Technology Forum: The Diesel Technology Forum is a non-profit educational organization that provides information on cleaner and alternative fuels and cleaner diesel technology. www.dieselforum.org

- Manufacturers of Emission Controls Association (MECA): Go to MECA's website for information on diesel emission reduction technologies and manufacturers of diesel retrofits. www.meca.org

- National Biodiesel Board: The National Biodiesel Board is the national trade association for the biodiesel industry. Visit their website for more information on biodiesel and locations of biodiesel distributors. www.biodiesel.org

- *Off-road Diesel Retrofit Guidance Document* (Western Regional Air Partnership [WRAP], November 2005): The WRAP is a voluntary organization of western states, tribes and federal agencies. It was formed in 1997 as the successor to the Grand Canyon Visibility Transport Commission to help the region comply with EPA's regional haze regulations. Use this document to help guide you through retrofitting a fleet. www.wrapair.org/forums/msf/offroad_diesel.html

- EPA National Clean Diesel Campaign (NCDC): The National Clean Diesel Campaign is an OTAQ program. NCDC is a public-private partnership that collaborates with businesses, government and community organizations, industry, and others to reduce diesel emissions and protect human health and the environment. www.epa.gov/cleandiesel

  Go to www.epa.gov/cleandiesel/publications.htm for informational publications.

- EPA Office of Air and Radiation: Visit this website for more information on diesel PM. www.epa.gov/airtrends/pm.html

- West Coast Collaborative: The West Coast Collaborative is the NCDC regional collaborative that serves Alaska, Arizona, California, Canada, Hawaii, Idaho, Mexico, Oregon, and Washington.

Contact the West Coast Collaborative for assistance in reducing diesel emissions.
www.westcoastcollaborative.org

APPENDIX I: ERRS AND RAC CONTRACT LANGUAGE

ERRS Language

Region 9 Emergency and Rapid Response Service (ERRS) contracts include the following diesel emissions reduction language.

> CLEAN TECHNOLOGIES
>
> The contractor will use clean technologies and/or fuels on all diesel equipment to the extent practicable and/or feasible. The preference is for clean diesel technologies, but alterative fuels, such as biodiesel or natural gas-powered vehicles are also acceptable. These alternative fuels will be used where they are available and within a reasonable distance to sites. For equipment retrofits, the contractor will employ the Best Available Control Technology (BACT) on non-road and on-road diesel powered equipment used at a site. Examples of clean diesel technologies include diesel particulate filters (DPFs), and diesel oxidation catalysis (DOCs). For alternative fuel usage, the contractor will use at least a B20 blend (e.g., 20 percent biodiesel and 80 percent petrodiesel) or higher in the equipment engines that are used at a site.

RAC Language

Region 9 Response Action Contracts (RAC) include the following diesel emissions reduction and renewable energy use language.

> Clean Air
>
> In the performance of all activities performed under this contract, the contractor shall where directed by EPA use cleaner engines, cleaner fuel and cleaner diesel control technology on diesel powered equipment with engines greater than 50 horsepower whether the equipment is owned or rented. Direction will be provided on a Task Order by Task Order basis. The contractor shall provide a break-out cost for each task order in accordance with the instruction in contract clause addressing submission of cost proposal.
>
> Cleaner engines include non-road engines meeting Tier I or cleaner standards and on-road engines meeting 2004 On-Highway Heavy Duty Engine Emissions Standards or cleaner, whether the equipment is owned or rented. Cleaner fuels include biodiesel blends or ultra low sulfur diesel. Cleaner diesel control technology includes EPA or California Air Resources Board ("CARB") verified diesel particulate filters ("DPFs") or diesel oxidation catalysts ("DOCs"). The contractor shall track emissions reduced (i.e., tons of diesel particulate matter reduced) associated with using cleaner diesel equipment and fuels.
>
> Renewable Energy
>
> The contractor shall evaluate all reasonably feasible renewable energy sources when conducting work related to selecting a cleanup remedy, constructing a cleanup remedy, and when optimizing an existing cleanup remedy. Sources of renewable energy include solar, wind, and biomass and biogas. Examples of renewable energy technologies include photovoltaic panels, wind turbines, digesters, gasifiers, and micro turbines. Part of evaluating renewable energy sources and technologies will involve a cost analysis, comparing the energy costs from renewable sources versus

traditional electricity sources provided by local utilities, over the expected life of the cleanup remedy. Similarly, an evaluation of the avoided emissions as a result of using renewable energy sources versus traditional energy sources provided by local utilities shall be performed. The contractor shall also evaluate the cost of purchasing green power from organizations that offer green power within the appropriate state.

APPENDIX II: FEDERAL REGULATIONS AND GOALS

The following are some federal regulations and goals that pertain to reducing GHGs and diesel emissions.

- Diesel Emissions Reduction Act of 2005 (DERA): DERA authorizes $200 million per year over five years in grants and loans for states and organizations to clean up existing diesel fleets.
- EPA Administrator's Action Plan:[280] This plan aims to provide certainty for consumers and protect the environment by seeking passage of Clear Skies (www.epa.gov/clearskies) legislation; expand the use of biofuels and promote diesel emissions reductions through retrofit and other technologies; promote clean air and energy security through voluntary conservation programs, such as Energy Star (www.energystar.gov) and SmartWay Transport (www.epa.gov/smartway); and make timely permitting decisions and foster technological innovations to support the clean development of domestic energy resources (oil, gas, nuclear, coal, wind, and solar).
- EPA Region 9 Energy and Climate Change Strategy:[281] Included in this strategy is the promotion of renewable energy production on contaminated sites by working with land owners and utilities to encourage the production/use of renewable energy on revitalized lands.
- Energy Independence and Security Act of 2007:[282] Signed into law by President George W. Bush on December 17, 2007, this act increases renewable fuel standards and raises fuel economy standards for cars, trucks, and SUVs. It also aims to further develop carbon capture technology.
- Energy Policy Act (EPAct) of 2005:[283] The EPAct 2005 was passed by Congress on June 29, 2005 and signed into law by President George W. Bush on August 8, 2005. It addresses growing energy problems, provides tax incentives and loan guarantees for energy production of various types. Each federal agency is required to increase renewable energy use and reduce energy intensity. Federal agencies are also required to purchase products that are Energy Star-qualified (www.energystar.gov) or designated by the Federal Energy Management Program (FEMP) (www1.eere.energy.gov/femp/procurement/index.html).
- Executive Order (EO) 13134 "Developing and Promoting Bio-based Products and Bioenergy":[284] Issued August 12, 1999, EO 13134 develops a comprehensive national strategy, including research, development, and private sector incentives, to stimulate the creation and early adoption of technologies needed to make bio-based products and bioenergy cost-competitive in large national and international markets.
- Executive Order 13148 "Greening the Government Through Leadership in Environmental Management":[285] Issued April 22, 2000, EO 13148 encourages integrating environmental accountability into agency day-to-day decision-making and long-term planning processes, across all agency missions, activities, and functions. It stresses that environmental management considerations must be a fundamental and integral component of Federal Government policies, operations, planning, and management.

- Executive Order 13221 "Energy-Efficient Standby Power Devices":[286] Signed on July 31, 2001, EO 13221 calls for Federal agencies to purchase products that use minimal standby power when possible.

- Executive Order 13423 "Strengthening Federal Environmental, Energy, and Transportation Management":[287] Signed on January 24, 2007, EO 13423 mandates new sustainability goals for the federal government that match or exceed previous statutory and EO requirements. It mandates an annual 3 percent reduction and cumulative 30 percent reduction in energy intensity by 2015 (compared to a fiscal year 2003 baseline) and requires that 50 percent of current renewable energy purchases come from new renewable sources—sources that have been developed after January 1, 1999. This requirement seeks to reduce GHG emissions and achieve in 10 years the same level of energy efficiency improvement that federal agencies achieved in the last 20 years. EO 13423 is 50 percent more stringent than the requirements of EPAct of 2005.

- Executive Order 13432 "Cooperation Among Agencies in Protecting the Environment With Respect to Greenhouse Gas Emissions From Motor Vehicles, Nonroad Vehicles, and Nonroad Engines": Signed on May 14, 2007, EO 13432 requires EPA to protect the environment with respect to GHG emissions from motor vehicles, non-road vehicles, and non-road engines. The Order calls for EPA to work in collaboration with the U.S. Department of Transportation (DOT) and the DOE in conducting research and developing policy. Key considerations in developing policy include sound science, analysis of costs and benefits, public safety, and economic growth.

- Greening EPA:[288] EPA continuously works to reduce the environmental impact of its facilities and operations, from building new, environmentally sustainable structures to improving the energy efficiency of older buildings. EPA is striving to significantly reduce its reliance on energy sources that emit GHGs. For more information, go to www.epa.gov/greeningepa. The EPA purchases Green Tags to offset 100 percent of its energy use in EPA facilities nationwide. The EPA strives to acquire alternative fuel vehicles, reduce its use of petroleum fuel, (improving its own fleet fuel efficiency by 3 percent annually) and encourage private sector organizations to follow its lead. Go to www.epa.gov/greeningepa/greenfleet for more information.

- National Clean Diesel Campaign (NCDC): The NCDC is a public-private partnership that collaborates with businesses, government and community organizations, industry, and others to reduce diesel emissions. NCDC is a program within EPA's Office of Transportation and Air Quality (OTAQ); contacts are in each EPA region. For more information, go to www.epa.gov/cleandiesel.

APPENDIX III: SOLAR POWER

MORE SOLAR PV TERMS AND DEFINITIONS

Azimuth Horizontal angle between a point in the sky and true north (Fig. 50). To optimize annual energy production, solar arrays should be oriented to face true south, i.e., with an azimuth of 180°.

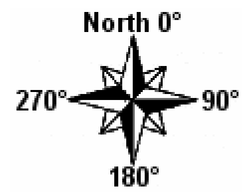

Figure 50 Azimuth. Image courtesy CSI[289]

Insolation Amount of solar energy received on a given area over time measured in kilowatt-hours per square meter (kWh/m^2).[290]

Irradiance The direct, diffuse, and reflected solar radiation that strikes a surface. Usually expressed in kilowatts per square meter (kW/m^2). Irradiance multiplied by time is insolation.[291]

Peak Sun Hours Peak sun hours are the hours equivalent to the number of hours per day with solar irradiance equaling 1,000 W/m^2. To determine peak sun hours, determine the energy from total sunlight throughout the day. Next, determine how many hours with solar irradiance equaling 1,000 W/m^2 this equates to. This is equal to peak sun hours. In other words, six peak sun hours means that the energy received during total daylight hours equals the energy that would have been received had the sun shone for six hours with an irradiance of 1,000 W/m^2.[292]

Tilt Angle Angle between the horizontal and the solar panel (Fig. 51). For maximum average annual insolation for a fixed-tilt PV system, the tilt angle should be equal to the latitude of the site. For maximum average insolation in summer months, the tilt angle should be equal to the latitude minus 15°. For maximum average insolation in winter months, the tilt angle should be equal to the latitude plus 15°.

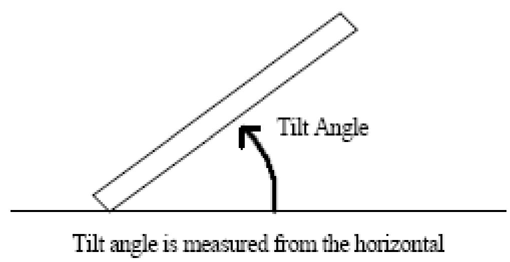

Figure 51 Tilt angle. Image courtesy Solar On-Line[293]

For more solar energy terms, go to EERE's Solar Glossary (www1.eere.energy.gov/solar/solar_glossary.html).

SOLAR PV TECHNOLOGY

Solar Cell[294]

PV cells are composed of at least two layers of semiconductor material, commonly silicon. Silicon has a valence of four, meaning that there are four electrons in its outer orbital. Each silicon atom shares one of its valence electrons with each of its closest neighboring atom in a covalent bond.

These electrons can be knocked loose by a photon, creating an electron-hole pair. The "hole" refers to the positive charge created by the loss of the freed electron. Electrons and holes can migrate given an electric field within the material. The strength of the current depends on the concentration density of free electrons and holes. A small fraction of the silicon atoms can be substituted with a different element, a process known as doping. An "n" type semiconductor is doped with an element having 5 valence electrons, usually phosphorus, making the layer negatively charged (Fig. 52).

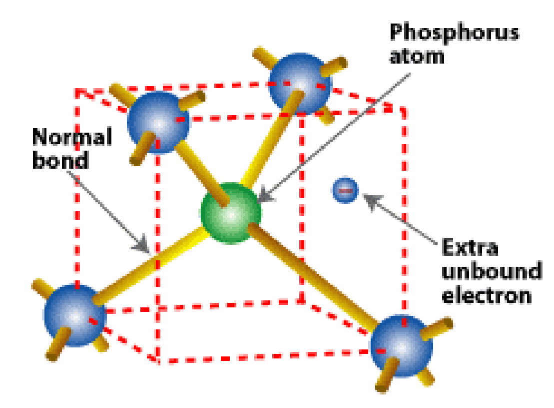

Figure 52 Substituting a phosphorus atom (with five valence electrons) for a silicon atom in a silicon crystal leaves an extra, unbonded electron that is relatively free to move around the crystal. Image courtesy EERE[295]

A "p" type semiconductor is doped with boron which has three valence electrons to create holes. A small amount of these impurities in the silicon does not alter the lattice structure but allows electrons on the n-type to be more easily freed and creates holes on the p-type semiconductor. Photons striking the cell releases electrons from the negative layer and they flow towards the positive layer (Fig. 53). A metal wire is placed separately on the p and n side to power a load with the induced current.

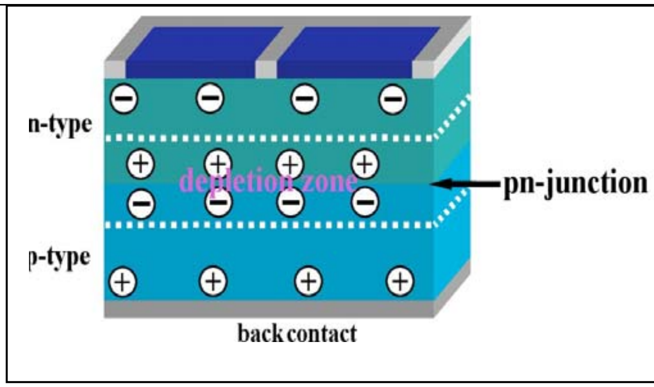

Figure 53 The pn-junction of a solar PV cell. Image courtesy Special Materials and Research Technology[296]

Series and Parallel Circuits

Each PV module is rated at a certain voltage and amperage. A 50-watt PV module is nominally 12 volts (DC) and three amps in full sun.[297] PV modules can be wired together to obtain different volts and amps to better suit the electricity needs of the site (Fig. 54). By wiring modules or batteries in series, voltage additively increases while amps do not change. Wiring modules or batteries in parallel will increase amps additively but voltage stays the same. To obtain required amps and voltages, modules and batteries may be wired with a combination of series and parallel circuits.[298]

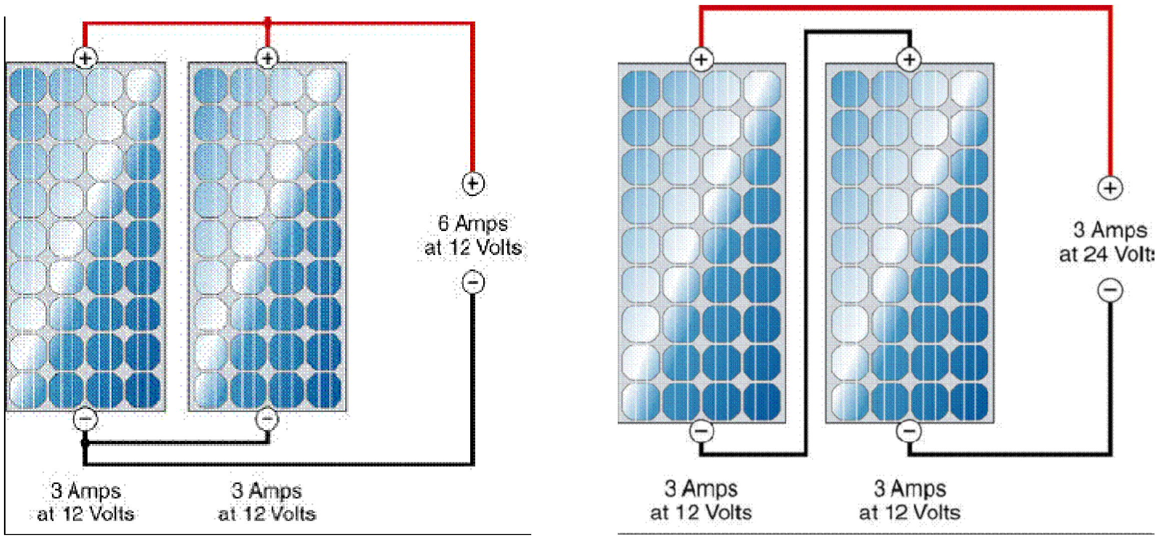

Figure 54 Parallel circuit (left) and series circuit (right). Images courtesy Solar On-Line[299]

Batteries

A battery is defined as two or more electrochemical cells enclosed in a container and electrically interconnected in an appropriate series/parallel arrangement to provide the required operating voltage and current levels. [300] Batteries can be used with any renewable energy system to store electricity for later use when the renewable energy system is not generating enough energy for a cleanup site's operations. For sites that are not grid-tied, batteries should be included in the renewable energy project if a constant electricity source is necessary. In these cases, the renewable energy system must be sized to provide enough electricity to power your site as well as charge the battery. Sites that are grid-tied can still consider including a battery to reduce reliance on the grid. There are many types of rechargeable batteries that can be used with your project. The two main categories of battery technology are lead-acid and alkaline. Lead-acid batteries are used with most renewable energy projects.[301]

Lead-Acid: Lead-acid batteries are rechargeable, widely available, relatively inexpensive compared to alkaline batteries, easily maintained, and has comparable longevity for the price. Lead-acid batteries are distinguished between deep cycle and shallow cycle batteries. [302]

Deep cycle: Lead-acid deep cycle batteries may be discharged for an extended amount of time up to 80 percent of their rated capacity and are compatible with renewable energy projects. Two types of deep cycle lead acid batteries are liquid electrolyte and captive electrolyte batteries.

Lead-acid deep cycle liquid electrolyte: Liquid electrolyte batteries are found on golf carts and forklifts. Most renewable energy systems use these batteries (Fig. 55). They vent hydrogen gas that is produced as the battery nears full charge. Some batteries may require periodic filling as water is lost through the vent. A properly sized and maintained deep-cycle liquid electrolyte lead-acid batter will last 3-10 years. The life of a battery depends on temperature and how deeply the batteries are discharged. A battery cycle is one complete discharge and charge. Batteries that operate on a cycle that discharges to 50 percent of capacity will last about twice as long as batteries that are discharged to 80 percent.[304]

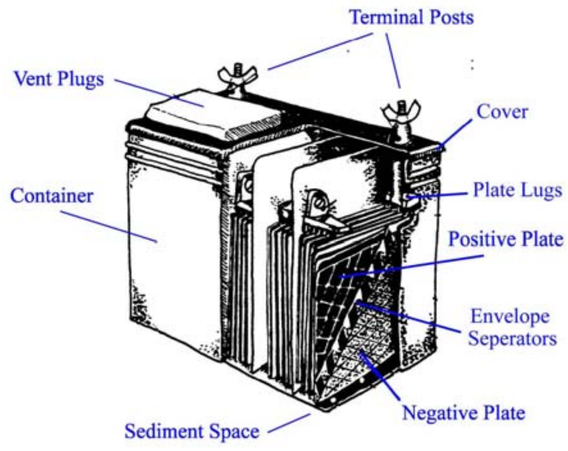

Figure 55 Liquid electrolyte lead-acid battery. Image courtesy Solar On-Line[303]

Lead-acid deep cycle captive electrolyte: Captive electrolyte batteries do not have a vent for electrolytes to escape. Therefore they require minimal maintenance though they are about twice as expensive as liquid electrolyte batteries. Less power is available in cold temperatures and high temperatures decrease battery life.

Shallow Cycle: Shallow cycle batteries, like car batteries, are discharged for a very short duration and are not recommended for renewable energy system use.

Alkaline Batteries: Alkaline batteries have higher voltages compared to lead acid batteries. They are not as effected by temperatures, can be deeply discharged, and have a useful life of about 30 years. They are significantly more expensive than lead-acid batteries. These are recommended for remote areas with extreme temperatures in cases where costs are not the most important issue.[305]

To properly size a battery for a renewable energy system, one must consider the following:[306]

Days of autonomy This refers to the number of days a battery system will provide enough energy for a load without recharging

Battery capacity Battery capacity is rated in amp-hours (AH). Theoretically, a “100 AH battery” will deliver one amp for 100 hours or roughly two amps for 50 hours before the battery is considered fully discharged.

Rate and depth of discharge The rate at which a battery is discharged directly affects its capacity. Discharging a battery over a shorter amount of time decreases its capacity. The depth of discharge refers to how much electricity is withdrawn from the battery. Shallow depths of discharge, which is to draw little energy from the battery compared to the battery capacity, prolongs battery life.

Life expectancy Life expectancy for batteries is measured in number of cycles (one discharge and one charge). Batteries lose capacity over time and are considered to be at the end of their lives when 20 percent of their original capacity is lost.

Environmental conditions Battery capacity is reduced at extreme temperatures.

To estimate the number of batteries you would need, look at the specifications offered for a battery and use the following equations (Fig. 56).

AC Average Daily Load	÷	Inverter Efficiency	+	DC Average Daily Load	÷	DC System Voltage	=	Average Amphours / Day
[(	÷	)	+	]	÷		=	
Average Amphours/day	x	Days of Autonomy	÷	Discharge Limit	÷	Battery Ah Capacity	=	Batteries in parallel
	x		÷		÷		=	
DC System Voltage	÷	Battery Voltage	=	Batteries in Series	x	Batteries in Parallel	=	Total Batteries
	÷		=		x		=	
Battery Specification			Make:				Model:	

Figure 56 Estimate number of batteries needed. Image courtesy Solar On-Line[307]

Controllers[308]

Controllers prevent batteries from being overcharged by the PV system and overly discharged by the load. The size of the controller is measured by its amps. Controllers can be wired in parallel if high currents are necessary. There are four different types of PV controls:

- Shunt Controllers -- Shunt controllers are designed for small systems and prevent overcharging by “shunting” or by-passing the batteries when they are fully charged. Excess power is converted into heat.
- Single-stage Controllers – Single-stage controllers switch the current off when the battery voltage reaches a certain pre-set value and reconnect the array and battery if the voltage falls below a certain value.
- Multi-stage Controllers -- Multi-stage controllers establish different charging currents depending on the battery’s state-of-charge.
- Pulse Controllers – Pulse controllers rapidly switch the full charging current on and off when the battery voltage reaches the pre-set charge termination point.

Inverters[309]

Inverters are necessary to change DC electricity produced by PV modules and stored in batteries to alternating current for use in AC loads. They are also needed to feed electricity into the utility grid. For grid-tied PV systems, contact the utility for inverter requirements.

Optimal features of an inverter:

- High efficiency – converts 80 percent or more of direct current input into alternating current output
- Low standby losses – highly efficient when no loads are operating
- High surge capacity – able to provide high current often required to start motors or run simultaneous loads
- Frequency regulation – maintains 60 Hertz output over a variety of input conditions

- Harmonic distortion – can "smooth out" unwanted output peaks to minimize harmful heating effects on appliances
- Serviceability – easily field-replaced modular circuitry
- Reliability – provide dependable long-term low maintenance service
- Automatic warning or shut-off – protective circuits which guard the system
- Power correction factor – maintains optimum balance between power source and load requirements
- Lightweight – to facilitate convenient installation and service
- Battery charging capability – allows the inverter to be used as a battery charger
- Low cost – inverters are about $700 per kW

Inverter Types

Inverters can be sorted into two categories. Synchronous (also known as line-tied) inverters are used with grid-tied PV systems. Static inverters are used with non-grid-tied PV systems. Inverters also produce different wave forms:

- Square Wave Inverters – appropriate for small resistive heating loads, some small appliances and incandescent lights
- Modified Sine Wave Inverters – appropriate for operating motors, lights, and standard electronic equipment
- Sine Wave Inverters – appropriate for sensitive electronic hardware

MORE QUESTIONS TO ASK YOUR POTENTIAL SOLAR INSTALLER[310]

- Is the company a full service or specialty firm?
- How long has the company been in business?
- How many projects like yours have they completed in the past year? In the past three years?
- Can they provide a list of references for those projects?
- What PV training or certification do they have?
- What can they tell you about local, state and national incentives?
- How much do they know about zoning and electrical requirements and codes?
- Do they offer adequate warranties?
- Does the company carry workers' compensation and liability insurance? Do their subcontractors, if applicable, carry liability insurance? Can they show you a copy of their policy?
- What permits are needed for this project? Who is going to obtain and pay for them?
- If applicable, will the city require a structural review of the roof by an architect or professional engineer? Who will pay for this service?

- Will they provide written guarantees on all materials and workmanship?
- What is the exact schedule of payments to be made? Besides materials and labor, does the estimate include sales tax, permit fees, structural analysis fees, interconnection fees, and shipping costs?
- How soon can they respond to a service call if the PV system is not working properly? Would they be the one to repair the system?
- What service do they offer after installation? Do they offer updates of manuals and catalogues?
- 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. Less expensive estimates may not include a service or device or may have hidden costs.

CONCENTRATED SOLAR POWER (CSP)[312]

Concentrated solar power technology can also convert solar power into electricity. Mirrors are oriented to focus heat from the sun to heat a liquid or gas in a tube to very high temperatures (Fig. 57). Energy from the liquid or gas can then be utilized in steam engine generators. CSP technology is less expensive than PV. However, current concentrated solar power projects are usually constructed at a large scale of greater than one MW, and may exceed the electrical needs of a cleanup. Companies that tailor CSP projects for industrial sectors are emerging. Go to www.nrel.gov/learning/re_csp.html for more information.

Figure 57 Parabolic-trough concentrating solar power system. Image courtesy NREL[311]

APPENDIX IV: WIND POWER

WIND TECHNOLOGY

Extracting Energy from Wind

The theoretical maximum efficiency for a wind turbine is 59 percent (the Betz limit). It is not possible to extract all the energy from wind. If total kinetic (motion) energy were extracted, there would be no wind passing through the turbine. You would need a solid disk to trap all the wind. But if this were the case, the wind would blow around the solid disk and no energy would be captured. Thus, wind blades can extract only a portion of the total wind energy.[313]

When air passes over a wind turbine's blade, it travels faster over the top of the blade than it does below. This makes the air pressure above the blade lower than it is underneath. Due to the unequal pressures the blade experiences a lifting force, causing the blades to spin. Since the wind turbine captured some kinetic energy from the wind, wind blows more slowly downwind of the turbine.[314]

Towers[315]

A general rule of thumb is to install a wind turbine on a tower with the bottom of the rotor blades at least 30 feet (9.1 meters) above any obstacle that is within 300 feet (91 meters) of the tower. Relatively small investments in increased tower height can yield very high rates of return in power production. For instance, a 10-kW turbine on a 100-foot tower costs 10 percent more than a 10-kW turbine on a 60-foot tower, but it can produce 29 percent more power.

There are two basic types of towers: self-supporting (free standing) and guyed. Most small wind power systems use a guyed tower. Guyed towers, which are the least expensive, can consist of lattice sections, pipe, or tubing (depending on the design), and supporting guy wires (Fig. 58). They are easier to install than self-supporting towers. However, because the radius of the circle created by guy wires must be one-half to three-quarters of the tower height, guyed towers require enough space to accommodate them. You may also opt to install tilt-down towers (Fig. 59), which lower the system to the ground for maintenance or during hazardous weather such as hurricanes. Although tilt-down towers are more expensive, they offer the consumer an easy way to perform maintenance on smaller light-weight turbines, usually 5-kW or less.

Figure 58 A 10-kW wind turbine with guyed lattice tower. Image courtesy NREL[316]

Aluminum towers are prone to cracking and should be avoided. Most turbine manufacturers provide wind energy system packages that include towers. Mounting turbines on rooftops is not recommended since vibrations from the turbines may damage buildings. This can lead to noise and structural problems with the building. Rooftops can also cause excessive turbulence that can shorten the life of a turbine.

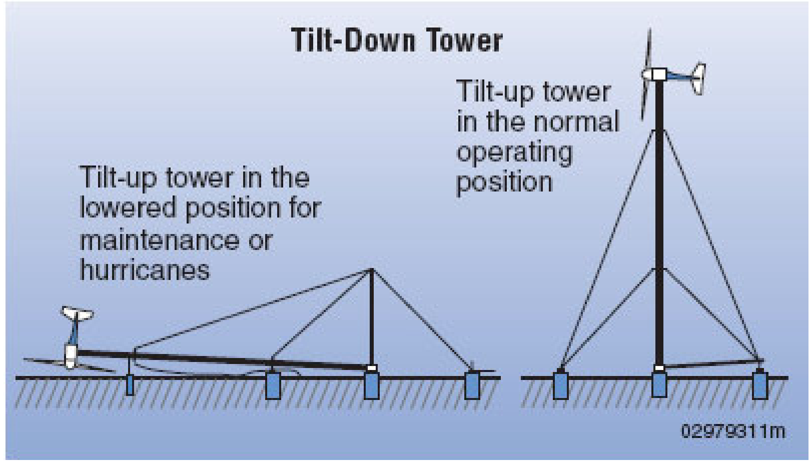

Figure 59 Tilt-down tower schematic. Image courtesy EERE[317]

CALCULATING WIND TURBINE OUTPUT POWER

See Box 11 for equations on estimating wind turbine output power with assumptions of blade length.

Box 11 Wind Turbine Output Power[318]
Step 1: Calculate swept area $$A = 3.14 * r^2$$ A = swept area r = radius, length of one blade, one-half of the diameter of the rotor
Step 2: Calculate power in the swept area $$P = 0.5 * \rho * A * V^3$$ P = power in watts (746 watts = 1 hp) (1,000 watts = 1 kilowatt) ρ = air density (about 1.225 kg/m^3 at sea level, less higher up) A = swept area (m^2) V = wind speed in meters/sec (20 mph = 9 m/s) (2.24 mph = 1 m/s)
Step 3: Calculate wind turbine power $$P = 0.5 * \rho * A * C_p * V^3 * N_g * N_b$$ P = power in watts (746 watts = 1 hp) (1,000 watts = 1 kilowatt) ρ = air density (about 1.225 kg/m^3 at sea level, less at higher altitudes) A = swept area (m^2) C_p = Coefficient of performance (0.59 [Betz limit] is the maximum theoretically possible, 0.35 for a good design) V = wind speed in m/s (20 mph = 9 m/s) N_g = generator efficiency (0.50 for car alternator, 0.80 or possibly more for a permanent magnet generator or grid-connected induction generator) N_b = gearbox/bearings efficiency (depends, could be as high as 0.95)

APPENDIX V: LANDFILL GAS-TO-ENERGY

PRELIMINARY EVALUATION WORKSHEET

Use the following worksheet to complete a preliminary feasibility evaluation of a LFGE project for an MSW landfill. (Worksheet created by LMOP)

Landfill Gas to Energy Project Preliminary Evaluation Worksheet[319]

A. Is your landfill a municipal solid waste landfill?

If not, you may encounter some additional issues in project development due to the presence of hazardous or non-organic waste in the landfill. Stop and consult an energy recovery expert.

B. Add your score for the next three questions:

1. How much MSW is in your landfill?

Tons	Score	
Greater than 3 million	40	
1-3 million	30	
0.75-1 million	20	
Less than 0.75 million	10	+Score____

2. Is your fill area at least 40 feet deep?

Yes = 5

No = 0 +Score____

3. Is your landfill currently open? If yes, answer 3(a). If no, answer 3(b).

(a) How much waste will be received in the next 10 years? For each 500,000 tons, score 5 points.

Total tons ÷ 500,000 tons x 5 points = +Score____

(b) If closed for less than one year, enter 0. If closed for one year or more, multiply each year since the closure by 5, and subtract that amount from the total score

Years since closure x 5 points = -Score____

Total your answers to questions 1-3: **Total Score**____

C. If your score is:

≥ 30: Your landfill is a good candidate for energy recovery (go to section D).

20-30: Your landfill may not be a good candidate for conventional energy recovery option. However, you may want to consider on-site or alternative uses for the landfill gas.

D. If your landfill is a good candidate, answer the following two questions:

1. Are you now collecting gas at your landfill (other than from perimeter wells), or do you plan to do so soon for regulatory or other reasons? If yes, your landfill may be an excellent candidate for energy recovery.

2. (a) Is annual rainfall less than or equal to 25 inches a year?

   (b) Is construction and demolition waste mixed into the municipal waste or is it a large portion of total waste?

If YES to questions D.2(a) or (b), your annual landfill gas production may be lower than otherwise expected. Your landfill may still be a strong candidate, but you may want to lower your estimated gas volumes slightly during project design and evaluation.

COMBINED HEAT AND POWER (CHP) [320]

Combined heat and power, also known as cogeneration, is an approach that increases efficiency from prime movers by generating and utilizing both electricity and heat. In conventional electricity generation, the electricity produced is utilized but the co-produced heat is often wasted. About 75 percent of fuel energy input into an engine is output as heat. In CHP applications, this waste heat is captured for space heating, water heating, steam generation to run a steam turbine, and cooling. Heat exchangers can recover up to 7,000 BTUs of heat per hour for each KW of the generator load. Utilizing waste heat can increase efficiency to 40-50 percent.

Go to EPA's Combined Heat and Power Partnership website (www.epa.gov/chp/) and see the EPA's Combined Heat and Power Partnership *Catalogue of CHP Technologies* (www.epa.gov/CHP/basic/catalog.html) for more information.

ELECTRICITY GENERATION

Details are provided below for the prime movers mentioned this guide. These include reciprocating engines, gas turbines, microturbines, boilers and steam engines, and fuel cells.

Reciprocating Engines / Internal Combustion (IC)Engine

Reciprocating engines, also called internal combustion engines, are a widespread and well-known technology. They require fuel, air, compression, and a combustion source to function. The two categories they generally fall into are (1) spark-ignited engines, typically fueled by gasoline, natural gas or landfill gas, and (2) compression-ignited engines, typically fueled by diesel fuel.[322]

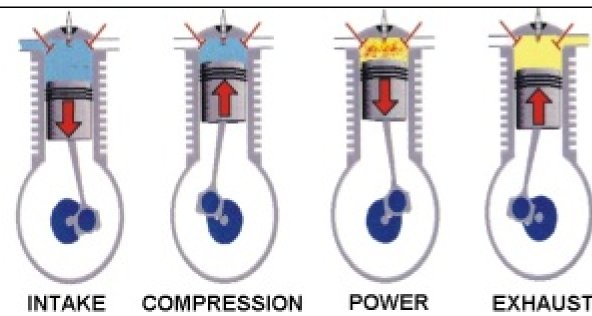

Figure 60 Reciprocating engine cycle. Image courtesy EERE[321]

How Does a Reciprocating Engine Work?

Four-stroke spark-ignited reciprocating engine process (Fig. 60):[323]

Intake: As the piston moves downward in its cylinder, the intake valve opens and the upper portion of the cylinder fills with fuel and air.

Compression: When the piston returns upward in the compression cycle, the spark plug emits a spark to ignite the fuel/air mixture.

Power: The piston is forced down, thereby turning the crank shaft and producing power.

Exhaust: The piston moves back up to its original position and the spent mixture is expelled through the open exhaust valve.

Applicability

Reciprocating engines can be used for landfill gas or biogas and are used in a wide variety of applications because of their relatively small size, low unit costs, and useful thermal output. For power generation, reciprocating engines are available in sizes ranging from a few kilowatts to over 5 MW.[324] The main advantage of reciprocating engines as compared to other power generation technologies is a better heat rate at lower capacities. Heat rate is the amount of gas needed to generate one kWh of electricity, and is closely related to system efficiency. The heat rate for a typical reciprocating engine plant is 10,600 BTU/kWh.[325] Another advantage of reciprocating engines is that the units are available in different incremental capacities, which makes it easy to tailor the IC engine size to the specific gas production rates of a landfill or digester.

Reciprocating engines are the most widely used prime movers for LFG-fired electric power generation.[326] Worldwide, there are more than 200 LFG-fired reciprocating engine power plants.[327] Reciprocating engines with power output from 0.1 MW to 3.0 MW have been proven suitable with landfill gas.[328]

Disadvantages of Reciprocating Engines

An important disadvantage of reciprocating engines is that they produce higher emissions of NO_x, CO, and NMOCs than other electric power generation technologies. However, significant progress has been made in reducing NO_x emissions in recent years. A second disadvantage to reciprocating engines is that their operation/maintenance costs on a per kWh basis are higher than for other power generation technologies. In general, reciprocating engines require a relatively simple LFG or biogas pretreatment process consisting of compression and removal of free moisture.[329] Water droplets are removed by the use of simple moisture separators (knockout drums), cooling of the biogas in ambient air-to-gas heat exchangers, and coalescing-type filters. Through compression and cooling, some of the NMOCs in the LFG are removed. The reciprocating engines can require 3-60 pounds per square inch gauge (psig) of fuel pressure.[330]

Information Resources

- EERE Distributed Energy Program Web Page: More information on gas-fired reciprocating engines. www.eere.energy.gov/de/gas_fired/
- *The California Energy Commission's Distributed Energy Resource Guide*: More information on performance, costs, strengths and weaknesses, and vendors of electricity generation equipment. www.energy.ca.gov/distgen/equipment/equipment.html

Combustion (Gas) Turbine (CT)

Landfill gas, digester biogas, and gasifier syngas can be used in gas turbines to produce heat and electricity. Gas turbines are heat engines that use high-temperature, high-pressure gas as the fuel. A portion of the heat supplied by the gas is converted directly into mechanical work.

How Does a Gas Turbine Work?

High-temperature and high-pressure gas rushes out of the combustor and pushes against the turbine blades, causing them to rotate. Gas turbines are often referred to as "combustion" turbines because in most cases, hot gas is produced by burning a fuel in air. Gas turbines are used widely in industry, universities and colleges, hospitals, and commercial buildings because they are compact, lightweight, quick-starting, and simple to operate.[331] Simple-cycle gas turbines convert a portion of input energy from fuel to electricity. The remaining energy produces heat which is normally expelled into the atmosphere. Simple-cycle turbines have efficiencies of 21-40 percent.[332] Combined-cycle gas turbines utilize high-quality waste heat to generate steam to power another turbine. The waste heat can also be used for cooling (e.g., absorption chillers), space or water heating, and other power applications. When taking advantage of the normally wasted heat, efficiencies increase to nearly 90 percent in some cases.[333]

Advantages and Disadvantages of a Gas Turbine

The main advantages of a CT as compared to a reciprocating engine are its lower air emissions and lower operation/maintenance costs. The main drawback to the combustion turbine is its high net heat rate. Combustion turbine net heat rates vary from 12,200 BTU per kWh to 16,400 BTU per kWh. Larger, new combustion turbines are more fuel efficient. Combustion turbines require a higher pressure fuel supply than reciprocating engines of 150-250 psig. Two stages of LFG compression are employed. Particles in the LFG have sometimes caused problems with the combustion turbine's fuel injection nozzles. A small water wash scrubber is normally provided in the pretreatment process to prevent this problem. [334]

For more information performance, costs, strengths and weaknesses, and vendors of electricity generation equipment, see *The California Energy Commission's Distributed Energy Resource Guide* (www.energy.ca.gov/distgen/equipment/equipment.html).

Microturbines

Microturbines are a relatively new technology. They are small combustion turbines, approximately the size of a refrigerator, with outputs of 30-250 kW.[335] Microturbines are best suited for relatively small applications that are less than 1 MW and for on-site electricity use or distribution to sites in close proximity.[336] They can be powered using landfill gas, digester biogas, or natural gas. Microturbines are ideal for LFGE or digester projects with low gas production or low methane concentration. A 30-kW microturbine can power a 40-hp motor or supply energy to about 20 homes.[337]

How do Microturbines Work?

Landfill gas, biogas, or other fuel, is supplied to the combustor section of the microturbine at 70-80 psig of pressure. Air and fuel are burned in the combustor, releasing heat that causes the combustion gas to expand. The expanding gas powers the gas turbine that in turn operates the generator; the generator then produces electricity. To increase overall efficiency, microturbines are typically equipped with a recuperator that preheats the combustion air using turbine exhaust gas. A microturbine can also be fitted with a waste heat recovery unit for auxiliary heating applications. They are different from traditional combustion turbines because they spin at much faster speeds.[338]

Applicability[339]

Microturbines provide advantages over other electrical generation technologies for landfills in cases where:

- LFG or biogas flow is low.
- LFG or biogas has low methane content.
- Air emissions, especially NO_x, are of concern (i.e., in NO_x nonattainment areas where the use of reciprocating engines might be precluded).
- Electricity produced will be used for on-site facilities rather than for export.
- Electricity supply is unreliable and electricity prices are high.
- Hot water is needed on-site or nearby.

Advantages

Compared to other IC engines, gas turbines and boiler steam-engine sets, microturbines have the following advantages.

- Portable and easily sized.
- Compact and fewer moving parts.
- Require minimal operation and maintenance.
- Use of air bearings coupled with air-cooled generator eliminates the need for lubrication and liquid cooling systems.
- Lower pollutant emissions (e.g., NO_x emissions levels from microturbines are typically less than one-tenth of those best-performing reciprocating engines and lower than those from LFG flares).
- Ability to generate heat and hot water.

Microturbine Concerns[340]

Microturbine long-term reliability and operating costs are not yet confirmed. They also have lower efficiencies than reciprocating engines and other types of turbines, by as much as 55 percent. Microturbines are more sensitive to siloxane contamination, so LFG needs more pretreatment measures to be used in a microturbine than in conventional engines.

For More Information on Microturbines

- EERE Distributed Energy Program Web Page : General information on microturbines. www.eere.energy.gov/de/microturbines/
- *"Powering Microturbines with Landfill Gas"* (EPA, LMOP): LFG-powered microturbine factsheet. www.epa.gov/lmop/res/pdf/pwrng_mcrtrbns.pdf

- *The California Energy Commission's Distributed Energy Resource Guide*: More information on performance, costs, strengths and weaknesses, and vendors of electricity generation equipment. www.energy.ca.gov/distgen/equipment/equipment.html

Boilers and Steam Engines

Boilers and steam engines may use landfill gas, biogas, or syngas to produce electricity. They are often most applicable for projects that can produce enough fuel for more than 10 MW of power. Since the steam cycle power plant emit lower air emissions than either reciprocating engines or combustion turbines, steam cycles have been preferred in regions with stringent air quality regulations, even when the size of the plant was relatively small.[341] While landfills usually produce less than 10 MW, more than 60 organizations in the U.S. are operating their boilers with LFG.[342] The steam cycle is at an economic disadvantage when compared to reciprocating engines and combustion turbines although the steam cycle power plant becomes more cost competitive as the size of the plant increases.[343] Net heat rates for the steam cycle are in the range of 11,000 BTU per kWh to 16,500 BTU per kWh. Steam cycles with higher temperature (1,000˚F) and pressure (1,350 psig), air preheaters, and up to five stages of feedwater heating, increase efficiency. The least efficient units operate at low temperature (650˚F) and pressure (750 psig), and are not equipped with air preheaters or feedwater heaters.[344]

See LMOP's factsheet, "Adapting Boilers to Utilize Landfill Gas" for more information (www.epa.gov/lmop/res/pdf/boilers.pdf).

Fuel Cells

Similar to a battery, fuel cells create electricity through the process of an electro-chemical reaction. This clean technology's byproducts are water and heat. The applicability of fuel cell use for is not widely established for landfill gas, biogas, and syngas. See the California Energy Commission website on fuel cells for more information: www.energy.ca.gov/distgen/equipment/fuel_cells/fuel_cells.html.

APPENDIX VI: ANAEROBIC DIGESTION

PRELIMINARY EVALUATION CHECKLIST FOR MANURE FEEDSTOCK

Checklist to Assess Digester Potential[345]

1. Facility Characteristics

a. Do you have at least 500 cows/steer or 2,000 pigs at your facility?	Yes □	No □
b. Are the animals confined year-round?	Yes □	No □
c. Is the animal population stable (varies less than 20% in a year)?	Yes □	No □

If the answer is YES to all the above questions, your facility is in good shape. Proceed to the next section. If the answer is NO to one or more of the above questions, the production and utilization of biogas as a fuel may not be suitable for your facility. For biogas production and utilization to succeed, a continuous and relatively consistent flow of biogas is required.

2. Manure Management

a. Is manure collected as a liquid (solids less than 4%), a slurry (solids less than 10%), or a semi-solid (solids less than 20%)?	Yes □	No □
b. Is the manure collected and delivered to one common point?	Yes □	No □
c. Is manure collected daily or every other day?	Yes □	No □
d. Is the manure relatively free of clumps of bedding, rocks, stones, and straw?	Yes □	No □

If the answers are YES to all the above questions, manure management criterion is satisfied. If the answer is NO to any of the questions, you may need to change your manure management routine.

3. Energy Use

a. Are there on-site uses for the energy recovered such as for heating, electricity, or refrigeration?	Yes □	No □
b. Are there nearby facilities that could use the biogas?	Yes □	No □
c. Are there electric utilities in your area that are willing to buy power from biogas projects?	Yes □	No □

If the answer is YES to any of the above questions, the energy use criterion is satisfied for initial screening purposes.

4. Management

a. Is there a person available on the farm who can operate and maintain the technical equipment?	Yes □	No □
b. If YES, can this person spend about 30 minutes a day to manage the system and 1-10 hours on occasional repair and maintenance?	Yes □	No □
c. Will this person be available to make repairs during high labor use events at the farm?	Yes □	No □
d. Is technical support (access to repair parts and services) available?	Yes □	No □
e. Will the owner be overseeing system operations?	Yes □	No □

If the answers are YES to all questions, there are promising options for gas recovery. Review the AgStar Handbook Chapter 3 (www.epa.gov/agstar/pdf/handbook/chapter3.pdf) to determine technical and economic feasibility of the project. If the answer was NO to any of the questions, you may need to make some changes. Evaluate the cost of the required changes before proceeding.

CALCULATING ENERGY POTENTIAL IN DAIRY MANURE[346]

How Much Power Can be Generated from 1,000 Dairy Cows?

Step 1: How much biogas can be produced from a farm with 1,000 dairy cows?

Assumptions:

- One dairy cow weighing 1,000 pounds generates 10 pounds (dry weight) of volatile solids (VS) per day (Source: American Society of Agricultural Engineering Standard).
- 60% of VS can be degraded during anaerobic digestion process.
- 12 ft^3 of biogas can be generated per pound of VS destroyed.

Volume of biogas produced daily:

$$= 1{,}000 cows \times 10 \frac{lbs(VS)}{cow-day} \times 60\% \frac{lb(VS)destroyed}{lb(VS)} \times 12 \frac{ft^3 biogas}{lb(VS)destroyed}$$

$$= 72{,}000\, ft^3 biogas / day$$

Step 2: What is the BTU content for the biogas produced from a farm with 1,000 cows?

Assumptions:

- Methane content in biogas is about 50%.
- Energy content of methane is 1,000 Btu/ft^3

BTU content of the biogas produced:

$$= 72{,}000 \frac{ft^3 biogas}{day} \times 50\% \frac{ft^3 methane}{ft^3 biogas} \times 1{,}000 \frac{BTU}{ft^3 methane}$$

$$= 36{,}000{,}000 BTU / day$$

Step 3: How much power can be generated using the biogas produced from a farm with 1,000 cows?

Assumption:

- The efficiency of a biogas fueled engine is 24% (Engine-driven generator has a heat rate of ~14,000 BTU/kWh)

Power production from 1,000 cows:

$$= 36{,}000{,}000 \frac{BTU}{day} \times \frac{1kWh}{14{,}000 BTU} \times \frac{1 day}{24 hours}$$

$$= 107 kW$$

Step 4: What is the estimated capital cost to install an anaerobic digestion to electricity system for a farm with 1,000 cows?

Assumption:

- The capital cost for an anaerobic digestion to electricity system is: $2,500 per kW. Note: Does not account for economies of scale.

Total estimated capital cost to build an anaerobic digestion system for a farm with 1,000 cows:

$$= 107 kW \times \frac{\$2{,}500}{kW}$$

$$= \$267{,}500$$

DIGESTER BIOLOGY

Anaerobic digesters produce methane from anaerobic bacteria breaking down organic material. Methane production in a digester is a three stage process (Fig. 61). First, bacteria decompose the organic matter into molecules such as sugar. Second, another group of bacteria convert the decomposed matter to organic acids. Finally, the acids are converted to methane gas by methane-forming bacteria.[347]

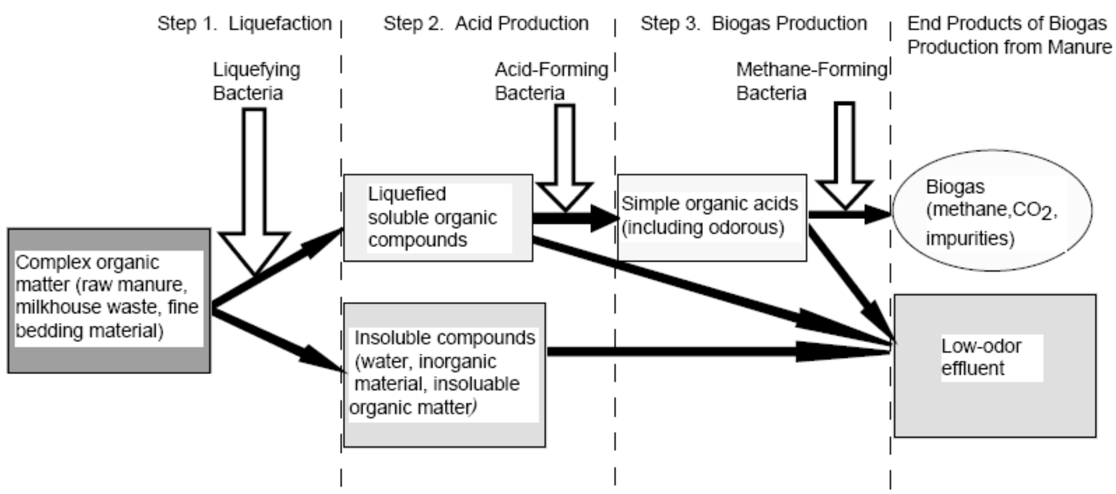

Figure 61 Stages of biogas production. Courtesy Penn State University[348]

Temperature is one of the most important factors in determining the rate of digestion and biogas production.[349] Anaerobic bacteria communities thrive best at temperatures of about 98°F (36.7°C) (mesophilic) and 130°F (54.4°C) (thermophilic).[350] Decomposition and biogas production occur faster in thermophilic conditions than in the mesophilic range. However, thermophilic bacteria are highly sensitive to disturbances, such as changes in feed materials or temperature. Mesophilic bacteria are less sensitive but the digester must be larger to accommodate for the longer HRT. Also, while all anaerobic digesters reduce the viability of weed seeds and pathogens, the higher temperatures of thermophilic conditions result in more complete destruction.[351] In most areas of the United States, anaerobic digesters usually require some level of insulation and/or heating if outdoor temperatures are too low. Digesters can be heated by circulating the coolant from the biogas-powered engines in or around the digester.

Other digestion rate and biogas production factors:

pH: Optimum biogas production is achieved when the pH value of input mixture in the digester is between 6 and 7.[352] In most digesters, the pH is self-regulating. Bicarbonate of soda can be added to the digester to maintain a consistent pH.[353]

Carbon-to-nitrogen (C:N) ratio: A C:N ratio ranging from 20:1 to 30:1 is considered optimum for anaerobic digestion. Organic materials with high C:N ratio could be mixed with those with a low C:N ratio to bring the average ratio of the influent to a desirable level (Table 11).[354]

Other factors that affect the rate and amount of biogas output include the liquid to solid ratio, mixing of the influent material, the particle size of the feedstock, and retention time. Pre-sizing and mixing of the feed material for a uniform consistency allows the bacteria to work more quickly. It may be necessary to add water to the feed material if it is too dry or if the nitrogen content is very high. Occasional mixing of the material inside the digester can aid the digestion process. Be aware that antibiotics in livestock feed may kill the anaerobic bacteria in digesters.[356]

Table 11 Carbon to Nitrogen Ratio of Various Organic Materials[355]

Organic Material	C:N Ratio
Cow manure	24:1
Swine manure	18:1
Chicken manure	10:1
Duck manure	8:1
Goat manure	12:1
Sheep manure	19:1
Straw (maize)	60:1
Straw (rice)	70:1
Straw (wheat)	90:1
Sawdust	>200:1

SLUDGE OR EFFLUENT

The digested organic material from an anaerobic digester is called sludge or effluent. It is rich in nutrients such as ammonia, phosphorus, potassium, and more than a dozen other trace elements.[357] Biomass digestion can also help reduce pathogens. For wastewater treatment sewage, operating digesters at mesophilic temperatures around 98-99˚F for 15 days results in 0.5-4.0 log reduction in fecal coliform, 0.5-2.0 log reduction in enteric viruses, and about 0.5 log reduction in protozoa and helminth ova. Operating digesters at thermophilic temperatures may reduce pathogens to non-detectable levels, depending on the solids-content and HRT (see 40 CFR 503.32(a) for calculations).[358] The digester sludge can then be used as a soil conditioner. Effluent has also been used as a livestock feed additive when dried. Be aware that toxic compounds (e.g., pesticides) that are in the digester feedstock material may become concentrated in the effluent. Therefore, it is important to test the effluent before using it on a large scale.[359]

APPENDIX VII: BIOMASS GASIFICATION

HOW DOES GASIFICATION WORK?[360]

The gasification process includes: (a) pre-treating the feedstock; (b) feeding it into the gasifier; (c) treating the generated syngas; (d) use of the syngas to produce electricity and heat; and (e) proper disposal of other byproducts. Inside the gasifier itself, biomass is added in either a dry form or mixed with water. The feedstock then reacts with steam and air or oxygen (O_2) at high temperatures (up to 2,600ºF) and pressure (up to 1,000 psig). To heat the gasifier, the char byproduct of gasification may be combusted.[361] The feedstock undergoes three thermal and chemical processes within the gasifier. There are a few types of gasifiers (updraft, downdraft, bubbling fluidized bed, circulating fluidized bed) but the following processes occur in each type:

1. *Pyrolysis*

   Pyrolysis is a chemical breakdown of complex compounds due to heat. It occurs as the organic matter heats up. Volatile substances such as tar, H_2, and CH_4 are released and a combustible residue resembling charcoal, called char, is produced.

2. *Oxidation*

   Then, volatile products and some char are burned in a controlled manner to form CO_2 and CO in a process called oxidation.

3. *Reduction*

   Last, in the reduction stage, the char reacts with the CO_2 and steam to produce CO and H_2, with some CH_4, which together make up syngas. The high temperature in the gasifier converts the inorganic materials left behind by gasification and fuses them into a glassy material, generally referred to as slag. The slag has the consistency of coarse sand. It is chemically inert and may have a variety of uses in the construction and building industries.

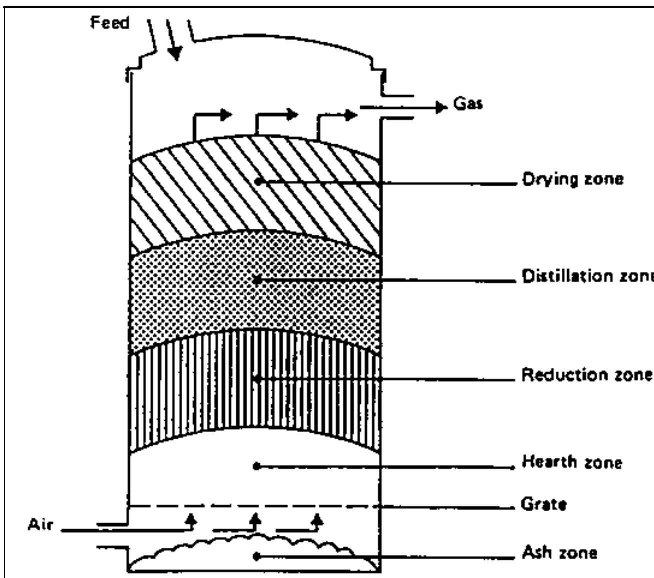

Figure 62 Updraft gasifier.
Image courtesy United Nations[362]

TYPES OF GASIFIERS[363]

Updraft Gasifier

The updraft gasifier is the oldest and simplest type of gasifier (Fig. 62). It is also known as counter-current or counter-flow gasification. Biomass is introduced at the top of the gasifier while air intake is at the bottom. Syngas leaves at the top of the gasifier.

Advantages:

- Proven technology, low cost process.
- Able to handle high moisture biomass and high inorganic content (e.g., municipal solid waste).
- Low gas exit temperatures and high equipment efficiency.

Disadvantages:

- Syngas contains 10-20 percent tar by weight, requiring extensive syngas cleanup before engine, turbine, or synthesis applications.

Downdraft Gasifier

The downdraft gasifier is also known as cocurrent-flow gasification (Fig. 63). Like the updraft gasifier, biomass is introduced at the top but in this case air is introduced at or above the oxidation zone in the gasifier. The syngas is removed from the bottom. The high-temperature syngas exiting the reactor requires a secondary heat recovery system.

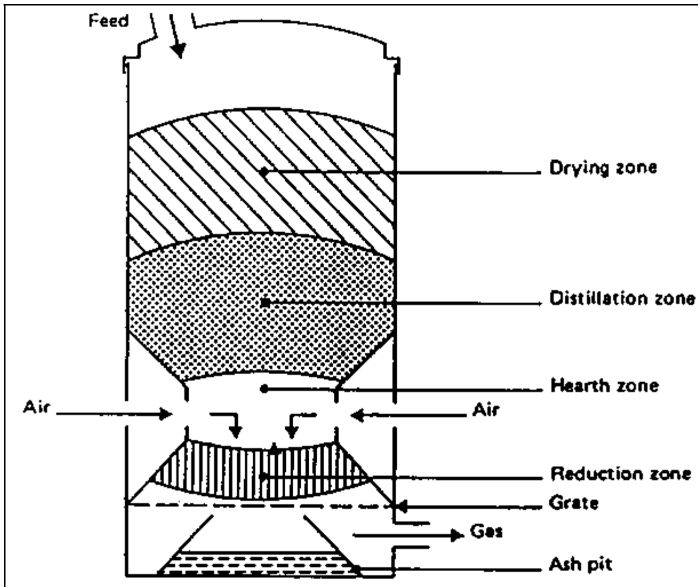

Figure 63 Downdraft gasifier.
Image courtesy United Nations[364]

Advantages:

- Proven technology, low cost process.
- Up to 99.9 percent of tar is broken down.
- Lower level of organic components in the condensate, less environmental objections than updraft gasifiers.

Disadvantages:

- Requires low moisture content feedstock (<20 percent) which necessitates a dryer.
- 4-7 percent of the carbon remains unconverted.
- Low density feedstock materials may cause flow problems and excessive pressure drop and the fuel may require pelletizing before use.
- May suffer from the problems associated with high ash content fuels (slagging) to a larger extent than updraft gasifier.

- The necessity to maintain uniform high temperatures over a given cross-sectional area makes it impractical to use downdraught gasifiers in a power range above about 350 kW.

Fluidized Bed Gasifier

In a fluidized bed gasifier, air, oxygen, or steam is blown through a bed of solid particles, such as sand or alumina, at a sufficient velocity to keep them in a state of suspension (Fig. 64). The “fluidized” particles can quickly break up and heat the biomass.

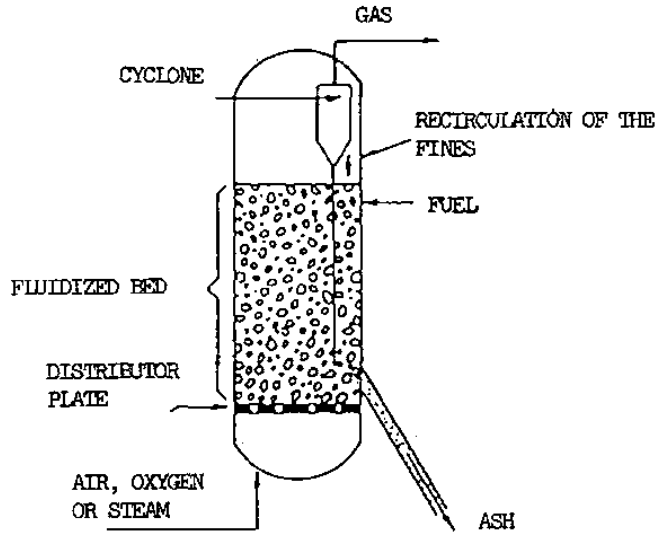

Figure 64 Fluidized bed gasifier. Image courtesy United Nations[365]

Advantages:

- Feedstock flexibility due to easy control of temperature.
- Can handle low density, fine grained feedstock (e.g., sawdust) without pre-processing.
- Yields uniform product gas.
- Suitable for rapid reactions.

Disadvantages:

- Poor response to load changes.

APPENDIX VIII: CLEANER DIESEL

VERIFIED TECHNOLOGIES

Use Table 12 to help evaluate which verified retrofit technologies are compatible with your off-road engines. Go to EPA's Verified Technologies List (www.epa.gov/otaq/retrofit/verif-list.htm) and CARB's Verified Diesel Emission Control Strategies List (www.arb.ca.gov/diesel/verdev/vt/cvt.htm) for technologies for on-road engines and stationary engines (e.g., electricity generators).

The EPA's Diesel Retrofit Program signed a memorandum of agreement (MOA) with CARB for the Coordination and Reciprocity in Diesel Retrofit Device Verification. The MOA establishes reciprocity in verifications of hardware or device-based retrofits, and further reinforces EPA's and CARB's commitment to cooperate on the evaluation of retrofit technologies.

Acronyms
*DPF: Diesel particulate filter
*DOC: Diesel oxidation catalyst
*EGR: Exhaust gas recirculation
*LSD: Low sulfur diesel. Diesel fuel with less than 500 ppm sulfur content.
*ULSD: Ultra-low-sulfur diesel. Diesel fuel with less than 15 ppm sulfur content.

Table 12 Non-Road Verified Retrofit Technology Options

Verified Technology for NON-ROAD Engines	**Minimum Engine Requirements**	**Potentially Applicable Engines**
Caterpillar Inc. Passive DPF www.cat.com EPA verified http://www.epa.gov/otaq/retrofit/techlist-cat.htm#dpf	Model year 1996-2005 Turbocharged 130 kW-225 kW Exhaust temperature of 260˚C for 40% of the cycle for NO_x:PM ratios of less than or equal to 20:1 and for NO_x:PM ratios equal to or greater than 25:1, only 200˚C for 40% of the cycle is required Fueled with LSD Complete requirements: http://www.epa.gov/otaq/retrofit/documents/verif-letter-cat2.pdf	Any engine that meets "Engine Requirements"
Engine Control Systems Combifilter Active DPF http://enginecontrolsystems.com CARB verified http://www.arb.ca.gov/diesel/verdev/level3/level3.htm	Model year 2007 or older Engine displacement ≤12 liters Must be able to return to regeneration panel after 8-10 hours of operation Fueled with LSD Complete requirements: http://www.arb.ca.gov/diesel/verdev/level3/eo_de04012_01.pdf	Must NOT belong to engine families found at http://www.arb.ca.gov/diesel/verdev/level3/ef_eode04012_01.pdf

HUSS Umwelttechnik GmbH FS-MK Series Active DPF http://www.huss-umwelt.com/en/ CARB verified http://www.arb.ca.gov/diesel/verdev/level1/level1.htm	Model year 2006 or older Complete Requirements: http://www.arb.ca.gov/diesel/verdev/level3/eo_de06007_01.pdf	Must NOT belong to engine families found at http://www.arb.ca.gov/diesel/verdev/level3/ef_de06007_01.pdf
Paceco Corporation Mitsui Engineering and Shipbuilding DPF Passive DPF http://www.pacecocorp.com/ CARB verified http://www.arb.ca.gov/diesel/verdev/level1/level1.htm	Must be a rubber-tired gantry crane 225 kW - 450 kW Achieves exhaust temperature of 250˚C or greater at least 50% of the time. Maximum consecutive minutes operating below passive regeneration temperature: 120 mins Max exhaust temp: 550˚C Fueled with ULSD or ≤B20 Complete Requirements: http://www.arb.ca.gov/diesel/verdev/ltrs/pacecomesdpfeo.pdf	Any engine that meets "Engine Requirements"
Donaldson DCM DOC DOC http://www.donaldson.com/en/index.html CARB verified http://www.arb.ca.gov/diesel/verdev/level1/level1.htm	Yard tractor, large lift trucks, top picks, side picks or gantry crane Model year 1996-2003 150 hp-600 hp Complete Requirements: http://www.arb.ca.gov/diesel/verdev/eodonaldsondoc88_90.pdf	Manufactured by the following companies AND listed in attachment below: Case Corporation Caterpillar Cummins Detroit Diesel Komatsu http://www.arb.ca.gov/diesel/verdev/level1/ef_donaldson_offroad.pdf
Engine Control Systems AZ Purifier and AZ Purimuffler DOC http://enginecontrolsystems.com/home.aspx CARB verified http://www.arb.ca.gov/diesel/verdev/level1/level1.htm	Port, railway, or other intermodal/freight handling applications Model year 1996-2002 Tolerate 20% reduced peak engine power No optical/conductive fuel sensors nor water absorbing fuel filters Must not use Bosch fuel pump VP30 nor VP44 Certified at PM emissions between 0.01 g/bhp-hr and 0.4 g/bhp-hr Fueled with ULSD Complete Requirements: http://www.arb.ca.gov/diesel/verdev/ltrs/azpurifieandpurimuffleeo.pdf	Manufactured by the following companies AND listed in attachment below: Case Cummins Navistar Komatsu http://www.arb.ca.gov/diesel/verdev/ltrs/purifilterenginefamilies.pdf
Extengine Inc. Advanced Diesel Emission Control	Rubber tired excavators, loaders, dozers, or utility tractor rigs Model year 1991-1995	Must be manufactured by Cummins

System DOC and SCR www.extengine.com CARB verified http://www.arb.ca.gov/diesel/verdev/level1/level1.htm	5.9 liter 150 hp-200 hp Duty cycle w/average exhaust >180˚C for at least 55% of operating cycle Turbocharged Mechanically controlled Requires pressurized anhydrous ammonia Fueled with LSD May incur 1% fuel economy loss Complete Requirements: http://www.arb.ca.gov/diesel/verdev/eode05001.pdf	

ENGINE FAMILY NAME

The engine family name is an alphanumerical code designated to engines by the EPA. It identifies engines by make, year, displacement, and emissions characteristics. It is important to get the engine family name for each engine as well as the individual specifications to facilitate the process of finding the appropriate retrofit device. EPA and CARB verify retrofit technologies for certain engines and other requirements, such as minimum engine temperature. The engine family name can be found on a sticker on the engine itself (Fig. 65). If this code cannot be found, retrofit technology dealers may be able to determine the family name from the other engine information provided. Off-road engines manufactured before 1996 typically do not have an engine family name.

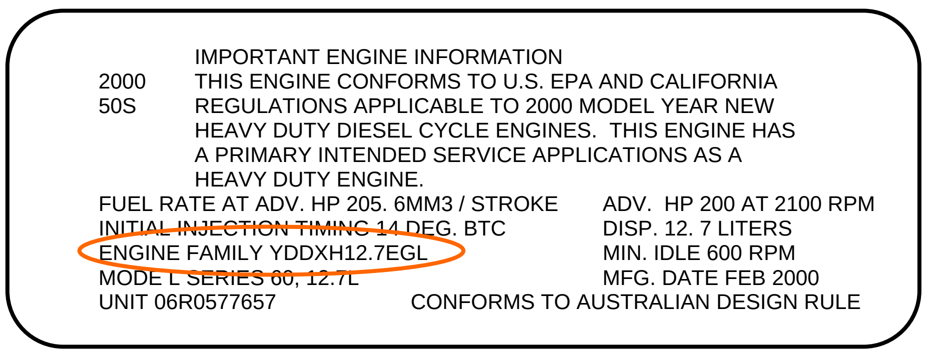

Figure 65 Sample engine emissions label with engine family name.[366]

ESTIMATING EMISSIONS FROM ON-ROAD TRANSPORT TRUCKS

Use the equations in Box 12 for a general estimate of NO_x, CO, and PM emissions from transport trucks to determine the approximate baseline emissions without pollution reduction measures.

Assumptions:

- Gas mileage of 6 miles per gallon
- Steady state operation of the trucks on interstate type roads

- Urban highway heavy-duty truck emission factors cited from *Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level: Final Report*, April 2005 by the DOT, Federal Highway Administration.

Box 12 Estimating on-road trucking emissions

Miles per Round Trip		Number of Trips		Emissions per Mile (g)		Total Emissions	
[ ]	x	[ ]	x	25.65	=	[ ]	Grams NO_x
[ ]	x	[ ]	x	2.48	=	[ ]	Grams CO
[ ]	x	[ ]	x	0.37	=	[ ]	Grams PM

APPENDIX IX: REGION 9 SUPERFUND ELECTRICITY AND DIESEL EMISSIONS INVENTORY

Superfund Electricity and Diesel Emissions Inventory
US EPA Region 9
Superfund

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August 16, 2007

Background and Goals

The Cleanup-Clean Air (CCA) initiative is a regional pilot program in US EPA Region 9. It is demonstrating the feasibility of using cleaner diesel vehicles and reducing greenhouse gases (GHG) in Superfund and developing tools to make it easier to do in the future. 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. Furthermore, the initiative strives to measure and reduce Superfund's environmental footprint, reduce exposure to Superfund communities, save energy costs in the long term, and serve as role model for other programs.

There were two specific goals set forth for this project within Cleanup-Clean Air. First, the project was designed to attain a rough estimate of the emissions footprint associated with remediation activities at Superfund National Priorities List (NPL) sites in Region 9. The second goal was to establish a baseline of electricity and diesel emissions to which any future measurable changes can be compared. Emissions associated with diesel equipment use and electricity production evaluated in this study include Carbon Dioxide (CO_2), Nitrogen Oxides (NO_x), Carbon Monoxide (CO), and particulate matter (PM). However, other pollutants such as Sulfur Dioxide (SO_2) and Polycyclic Aromatic Hydrocarbons (PAHs) are also present in diesel exhaust and combustion of fossil fuels for electricity production. Some of the associated health effects are listed below (EPA 2007a).

CO_2 : High concentrations of this greenhouse gas (GHG) are most significantly linked to global climate change.

PM: 90% of PM is $PM_{2.5}$. Exposure is linked to premature mortality, chronic bronchitis, chronic obstructive pulmonary disease (COPD), asthma aggravation, pneumonia, and heart attacks.

NO_x : Is a precursor causing ground level ozone (smog) through a series of atmospheric chemical changes. It contributes to global warming, acid rain, low visibility, deteriorated water quality, and a myriad of respiratory problems.

CO: Exposure affects human health in several ways. Depending on the concentration, CO can cause fatigue, flu-like symptoms, loss of brain function and even fatality. It affects the ability of blood to absorb oxygen. CO is also oxidized to form CO_2 in the atmosphere.

SO_2: Contributes to and aggravates respiratory illnesses; contributes to formation of acid rain; and it forms atmospheric particles that refract light and decrease visibility.

PAHs: Are highly carcinogenic compounds such as benzene and formaldehyde that are found in diesel emissions.

Methods

Information collected centered on construction activities (past, present, and projected future); specifications of treatment systems; past fuel and electricity use, and types of diesel equipment used for remediation activities (models and hours operating). Surveys were developed and distributed to Remedial Project Managers (RPMs) in two branches (Federal Facilities Branch and Site Cleanup Branch) of EPA Region 9's Superfund division. Data were collected through use of the surveys and personal meetings with each RPM, review of their associated site design documents, and contact with their contractors. *See Appendix E.*

The response rate for the surveys was roughly 50%, and therefore, emissions were only estimated for the sites that had completed surveys. Limited detail of information available for past remediation activities necessitated a method for creating rough estimates of emissions for sites with the incomplete information. Extrapolations and assumptions from the data were made and recorded, and consistent methods were applied across the data set when not otherwise specified. Assumptions involving site conditions, remedy design, construction and operations were made when the records were not available. A professional cost estimator from the Army Corps of Engineers was used to provide industry averages of typical equipment and associated operating times based upon the size and scope of the standard projects. *See Appendices A for a list of emissions assumptions regarding diesel and electricity, B for a list of assumptions that estimate equipment use for construction activities, and Appendix C for list of assumptions that encompass emissions estimates for diesel barges.*

To calculate the total mass of pollutants emitted (in grams), the following formula was used:

Pollutants Emitted = **hours x horsepower x EF (g/bhp-hr)**

where,

Hours: Hours were determined by assuming the amount of time each piece of equipment operated
Horsepower (hp): Assumed to be an average of 330 hp for all pieces of equipment unless otherwise specified. 330 hp represents a midsized piece of equipment and should even out with larger and smaller pieces of equipment used at each site.
Emissions Factors (EF): Were provided by Sacramento Air Resources Board for each standard assumed piece of equipment that was used in their emissions inventory model, ***Road Construction Modeler.Ver5.2.xls*** **(Christensen 2007)**. Units are measured in grams/brake-horsepower-hour (g/bhp-hr). EFs are also equipment specific (grader, off-highway truck, excavator, etc), model year specific, and operating year specific.

This formula was applied to each piece of equipment for individual construction activities conducted on sites, and the total grams for each individual pollutant (NO_x, CO, and PM) were aggregated and converted to tons. When unavailable, a model year was assumed for each piece of equipment to attain the EF. This was done by using the median use life of an equipment piece and subtracting it from the year construction commenced. (S*ee Appendix D*). It was also assumed that for the general estimating purposes of this project, bhp-hr and hp-hr were equal.

There were also certain construction activities that were omitted because there were no EFs available or because the information gaps in records regarding scale of projects made estimations impossible. Future projections, beyond 2009, were also estimated for known projected remediation activities.

Estimations of emissions associated with electricity consumption were conducted by gathering records of actual yearly kWh averages consumed at remediation sites. For sites without available electricity records, specifications of treatment systems were gathered that summarized the treatment facility type, number of extraction wells, flow rates, and dates of operation. These specifications were then inputted into the independent cost estimation software, Remedial Action Cost Engineering and Requirements (RACER), version 2006, developed by Earth Tech, Inc. and the Army Corps of Engineers (Earth Tech 2006.) Several assumptions about system conditions were made that are listed in *Appendix A.* This software provided an estimated amount of kWh needed to operate each specific treatment facility. Electricity amounts from both site records and RACER estimates were combined to get a total kWh consumed over time (1990-2009) for each site. Future projections were also established based on known treatment systems that will be operational for decades beyond 2009. EPA's database Emissions and Generation Resource Integrated Database (eGRID), released April 2007, was used to estimate tons of CO_2 associated with electricity production from the utility companies in the area (EPA 2007b). The database provided an average, "statewide" factor that was multiplied by kWh to attain CO_2 emissions.

Results

See Appendix F for Results Tables and Charts

Results pictured for emissions from both diesel exhaust and electricity production are approximately 50% of all Region 9 NPL sites surveyed. Although this information is not complete, data may be collected from the remaining sites in the future. Until that time, results for the whole region can be roughly estimated by multiplying these results by a factor of 2 and noting the assumption.

Total diesel emissions from 1985-2009 were estimated to be 3,140 tons NO_x, 848 tons CO, and 105 tons PM. The highest period of NO_x output was from 2000-2004 with 1,339 tons. The highest period of CO output was 1995-1999 with 268 tons. Lastly, the highest period for PM output was 2000-2004 with 38 tons. The lowest period of output for all pollutants was 1985-1989 with 186, 93, and 11 tons for NO_x, CO and PM respectively. It should be noted however, that although PM output was significantly lower in mass, the microscopic properties of the particles make this pollutant especially dangerous to human health by bypassing the body's natural defenses, such as cilia in the lungs.

Total CO_2 emissions associated with electricity consumption from 1990-2009 for Region 9 sites were estimated to be 428,174 tons. This is the equivalent of 84,000 cars on the road for one year or powering about 50,000 single family homes for one year. Future projections based only on known treatment facilities on grid as of 2007, Superfund is expected to use an additional 113.2 million kWh per year, equating to about 44,600 tons of CO_2. This would be equivalent to adding an additional 8700 cars or 5100 homes per year projected out for decades. (EPA 2005)

Discussion

As stated previously, the level of detail sought for emissions estimates was not always available from the RPMs when completing the surveys. This is because much of the information was tracked on a sub-contractor level, far from RPM involvement. It was especially difficult to obtain complete, detailed information of site remediation from the past, as many records were not preserved at a level regarding detail of fuel and electricity consumption or equipment associated with construction activities.

It is recommended that this information be tracked in the future. If specific information associated with emissions (i.e., gallons used, type of equipment used, and kWh consumed) is tracked throughout the life of the remediation activities, it is much easier to estimate the GHG emissions associated with each activity. Furthermore, the information gathered in this study, combined with detailed future tracking may help to normalize our data. In the future, it could be taken to the next step by putting it into a form that can be applied to all activities. For example, to achieve a baseline at any given point, we could calculate the emissions for each pound of contaminant removed during remediation.

The initial steps of tracking this information for Region 9 have already begun through inputting conditions into contract language. Regions 9 and 10 now have Emergency and Rapid Response contracts, and Region 9 is soon to have Remedial Action contracts in place that are or will soon require contractors to track use of cleaner diesel equipment, energy efficiencies, and renewable energy to power remediation on sites.

It is important to note that although results for diesel emissions are pictured within 5 year periods over the course of 25 years, the data is really a historical snapshot of past emissions rather than a trend. This is because the diesel work takes significantly less time in relation to electricity use for remediation. Generally, using heavy diesel equipment to complete construction activities on-site is accomplished on the time scale of several months to several years. In contrast, remediation that is tied into the electricity "grid" is conducted for decades or longer. It still may have fluctuations resulting from commencement or termination of treatment systems, but it is expected that these treatment facilities remain more stable in their electricity use and consequently the associated emissions. Therefore, fluctuations in diesel use over time may be a reflection of the phase of remediation at the Superfund site rather than a trend-like increase or decrease.

This emissions inventory also has applications beyond regional remediation. The process for collecting this data as well as the picture of our emissions footprint will help to inform larger Office of Solid Waste and Emergency Response (OSWER) efforts to estimate emissions across all regions. Furthermore, this data can likely be applied to EPA's COBRA model to quantify health care costs (in dollar amounts) associated with human health exposure to pollutants resulting from remediation activities.

We have quantified measurable adverse impacts to air quality resulting from remediation activities. While the estimates are rough, they provide an idea of our emissions footprint and clarified the need to track this information in the future for more accurate emissions inventories.

Possible mitigation of these impacts to air quality includes the use of cleaner diesel equipment, energy efficiencies, and renewable energy technologies. The Smart Energy Resource Guide (SERG) is currently being developed as a "one stop shop" tool for RPMs to implement these mitigation techniques and gain insight into reducing their emissions footprint at each of their Superfund sites.

Citations

1. Christensen, Peter. Sacramento Air Resources Board. Emissions Factors for Diesel Construction Equipment. Road Construction Modeler.Ver5.2.xls. Provided August 2007.

2a. Environmental Protection Agency. Air Pollutants. Updated May 2, 2007. http://www.epa.gov/air/airpollutants.html Accessed August 10, 2007.

2b. Environmental Protection Agency. eGRID (Emissions and Generation Resource Integrated Data Base). Released April 2007.

3. Environmental Protection Agency. Global Warming Calculators. “Equivalencies.” Updated June 27, 2005. http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterToolsCalculators.html Accessed August 10, 2007.

4. Earth Tech Inc. RACER (Remedial Action Cost Engineering and Requirements). Version 2006. http://talpart.earthtech.com/RACER.htm

5. McMindes, Daniel. US Army Corps of Engineers. Construction Estimates for Diesel Equipment. Provided July 2007.

Appendix A

List of Assumptions

Diesel Estimates

1. Assumed standard pieces of equipment provided by Army Corps of Engineers. See Appendix B.
2. Assumed 330 horsepower for all pieces of equipment
3. Assumed 1999 EFs for all construction activities using equipment on or before 1999.
4. For all construction after 1999, used EFs that fell closest to the year the EFs were available (1999, 2002, 2005, 2008, and 2010). For example, equipment used in 2001 would use a 2002 emissions factor.
5. For all Heavy Trucks (20 yd, 15 yd, and other hauling trucks), used an Emissions Factor configuration from Sacramento Air Resources Board. EFs were done for 5 year intervals averaging models from 1965 to year of EF. Assumption made to round down to closest 5 year interval from time the truck was used. For example, a truck used in 2002 would have a 2000 EF. These EFs assume 30 mph for all heavy trucks.
6. Assumed water trucks and hydro-seed trucks to be “off-highway”. Assumed cement, slurry, 15-yd, and 20-yd trucks to be on-highway trucks.
7. Construction activities not accounted for because of incomplete information: pumping hazardous liquids, helicopter flights, building demolitions, carbon regeneration.

Electricity Estimates

1. RACER assumption for groundwater extraction wells of unconsolidated, sandy-silt soil, 50 ft to top of contamination, and 75 ft to base of contamination.
2. RACER assumptions for contamination levels are 500 ppb influent, 5 ppb effluent.
3. RACER assumptions for GAC treatment systems include dual capacity system for higher flow rate systems (above 200 gpm).
4. Assumed flow rate for each extraction well is equal and adds up to total flow rate of treatment facility.
5. Assumed an average Emissions Factors by state where power production occurred. This factor provided by eGRID.

Appendix B	**Equipment Estimates from Dan McMindes**			
CONVERSIONS				
1 acre= 43,560 sf				
1 cy= 27 cubic feet				
1cy=1.35 tons or 1 ton=0.74 cy				
1 US Gallon=0.00495 cy				
Some unit assumptionsunless otherwise specified:**				
Excavation depth to get sf: 2'				
Landfill depth to get sf: 15'				
wells to get lf: 50' depth/well				
Cap: Assume 4 feet fill (2' low perm and 2' veg layer-->add inches that are specified to total volume if under 12" b/c it usually means an additional impermeable layer				
Hauling trucks *nearby import and haul with ~6mi roundtrip for total of 75 mi per day.				
Remediation Activity	**Activity Components**	**Units**	**Units/day**	**Construction Equipment**
Excavation and Backfill	clear and grub	sf	128,000 sf/day	scraper
assumptions	excavation	cy	480cy/day	excavator
no benching	offhaul near site	cy	120cy/day	15 yard truck
easy excavation no rock/boulders	import fill	cy	120cy/day	15 yard truck
small sf to cy ratio	backfill and recompact	cy	480cy/day	roller/sheepsfoot compacter
			with compactor	water truck
	rough grade site	sf	40000 sf/day	scraper/grader
	fine grade site	sf	40000 sf/day	scraper/grader
4 15cy trucks one day 15 minutes per round at approx 30 miles per hour would generate approx 75 miles per day per vehicle	*12 rounds/day holding 10 cy per load assuming 6.25 mi round trip=75 mi/day*			
soil aeration	rip soil 6 inches	sf	10000sf/day	dozer with rippers
8'wide x 1000' long 6 to 12" deep				

Landfill Capping				
use clear and grub above for grading operations	clear and grub	sf	128,000 sf/day	grader/scraper
fill with 2 feet of low perm	rough grade	sf	40000 sf/day	grader/scraper
fill with 2 feet of veg layer	import fill	cy	160cyd/day	20 cyd end dumps
	backfill and recompact	sf	480cy/day	roller/sheepsfoot compacter
			with compactor	water truck
	import fill	cy	160cyd/day	20 cyd end dumps
	backfill and recompact	sf	480cy/day	roller/sheepsfoot compacter
			with compactor	water truck
	fine grade	sf	40000 sf/day	grader/scraper
revegetation	water truck	sf	42000sf/day	
	hydroseed equipment/truck	sf	42000sf/day	
clay capping same as landfill capping				
dewatering same as aeration				
well installation	push type rig	lf	100lf/day	sampling rig
	drill type rig	lf	400 lf/day	hollow stem auger
hauling is the same as import or export				
ust removal is like excavation, but add cy for backfill and add a crane for 4 hours per tank as well as a truck for 4 hours to haul the tank away				
slurry walls under 12 feet deep	excavate and stockpile	lf	100lf per day	backhoe
	add slurry		80cy/dy	slurry truck
	offhaul excess soils	100*12*2/ 27=88.88	120cyd/dy	15 cyd truck
J.H. Baxter--example from Travis Cain	*Construction of a slurry wall (4377'x 2' width, slurry wall depth 50 ft); and 2 bioventing blowers at 500 cf/min;*	*slurry=162 11 cy; drilling: 218850 lf;*	*hollow stem auger: 547.1 days; sample rig: 2188.5 days; slurry truck: 202.6 days; 15 cy truck: 135.1 days*	
slurry walls over 12 feet use same effort as drill rigs plus effort for slurry and offhaul above, * *leave out the excavate and stockpile*				

fencing			500lf per day	pickup (ignore this)
assume all bushes and brush and trees gone				backhoe with auger attachment
Pipeline		36" diam-->	300 lf/day	Excavator to dig
		60" diam---> 150 lf/day		Backhoe with sheepsfoot attachment to backfill
				Water truck for same time as backhoe
Dams treat as fill		concrete dam	10 cy/day	concrete truck
		earthen dam	fill (cy to place and compact)	15 yd trucks, sheepsfoot roller, (see excavation)
Sediment ponds are same as excavation				
Removal of drums of Haz Waste		similar to excavation, but double the time it takes to remove.	240 cy/day	excavator 330 hp
			10 barrels per truck	Hauling truck (assume 200 hp)
			20 barrels/day	forklift to put on truck 330 hp
		backfill and recompact	480 cy/day	roller/sheepsfoot compactor 330 hp
			same time	water truck
15cy truck will hold between 8 and 10 cyds depending on density and weight of material. Assumed 10.				
All equipment is assumed to be 330 hp				

Appendix C

Emissions Estimates for Diesel Barges

Puget Sound Maritime Emissions Inventory: Used to estimate emissions from diesel barges when capping sediments.

Horsepower ranges from 40-350 hp, with the average barge engine having 188 hp.
*Assumed 1 engine (propulsion)—some have more than one, auxiliary and propulsion
*Assumed a median use life, since unavailable, to be 7 years (2001 model year).
*Assumed this was a non-road model, not an ocean going vessel (OGV)
*Assumed 130 kW Tier 1 (2001) engine
- Emissions from this engine are 9.8 g/kW-hr NO_x, 1.5 g/kW-hr CO, and 0.4 g/kW-hr for PM.

*Formula is <XX g/kWh x Hours x kW engine>
*Assumed barges hold ½ ton of material for capping per load. Estimated area of cap and volume needed to cover area to determine approximate miles vessel would travel. Then assumed 5 mph to estimate total hours in the water

See Table 4.7, page 273
http://www.maritimeairforum.org/emissions.shtml

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Appendix D

Median Use Life Provided by Road Construction Modeler

Backhoe: ½ use life= 8 yrs

Bore/Drill Rigs: ½ use life= 2 yrs

Crane: ½ use life= 5 yrs

Dozer: ½ use life= 8 yrs

Dredgers: Not available. Assume 5 yrs

Excavator: ½ use life= 4 yrs

Forklift: ½ use life= 4 yrs

Grader: ½ use life= 5 yrs

Generator: not available. Assume 8 yrs

Loaders: ½ use life= 3 yrs

Off Highway Trucks (Water Truck and Hydro-seed Trucks): ½ use life= 5 yrs

Pumps: ½ use life= assume 5 yrs

Roller: ½ use life= 4 yrs

Appendix E

Site Survey

Site Name:
ID #:
Location (county & state):
RPM:

As part of the Cleanup-Clean Air initiative, the Superfund Program is trying to reduce our emissions footprint at cleanup and redevelopment sites. In order to implement greener cleanup practices, we are first trying to gain insight into our energy use trends (past, present, and future), and corresponding emissions produced. The information you provide is invaluable in ascertaining knowledge we can put forth into further greening our operations in Region 9, so please be as specific as possible. If any information is already filled in for your site, please confirm its accuracy. If any projects are missing on the tabs, please contact Ashley DeBoard (7-4109) immediately so that she can help reformat your workbook. Furthermore, if more OUs are listed for your site than you are responsible for, please answer only for YOUR OUs. For those RPMs who may still be in "Pre RA" phase (see below), feel free to add any info you have available in the "Present RA" questions, regardless if they are rough estimates. Thank you for your time and effort; it is deeply appreciated.

1. What is the Lead type for your site? (Fund, PRP, Federal) If more than one Lead applies to your site, please list who is directing the current phase by OU or area.

2. How many operable units are at this site?

3. What phase is each of the operable units in? Please specify if the stage is planned or complete.
   a. Pre Remedial Action? Circle One (RI/FS, ROD, RD)
   b. Present Remedial Action? (RA, LTRA, O&M)

4. (Pre RA only)
   a. If no ROD, what are the contaminated media, and an approximate size of contamination? *(i.e.* yd^3 *of soil, volume/dimensions of groundwater plume)* Can you predict a method, or range of methods of remediation?
   b. If plan is in place, what are the estimated energy needs and an approximate length of time the OU will be active? Please give answers concerning energy needs in units of kW hrs/year and gallons of diesel fuel/ appropriate time frame (years, months, weeks).

5. (Present RA) How long will each operable unit be actively remediated?
   a. Diesel: (If applicable) How long will use of a diesel fleet be required to remediate contamination?
   b. Electricity: (If applicable) How long will use of grid power be necessary to maintain remediation operations at site?

6. (Present RA) DIESEL: **(For each OU)**

a. What are the *types* of diesel equipment being used in your fleet?
b. How many of each type are being used?
c. What is the time frame of their use?
d. What was the previous fuel consumption in the life of the RA unit? How has it changed, and over what time periods?
e. What is the amount of current fuel use? (Please specify units) *ex: 1000 gal/month/vehicle or OU*
f. Will the fuel use on the site decrease or increase in the future and when? Please specify how rate of fuel consumption will change over different time periods. *(ex: fuel use will drop from 1000 gal/mo to 500 gal/mo after 10 months, and to 250 gal/mo after 24 months. The project for OU-02 will be complete in 4 years.)*

7. (Present RA) ELECTRICITY: **(For each OU)** ***This info can be obtained from a utility bill.*

a. What is the type of facility/equipment requiring grid power?
b. What is the time frame of its electricity use?
c. What was the previous level of electricity consumption in the life of the RA unit? How has it changed, and over what time periods?
d. What is the amount of current electricity use (kW hrs/year)?
e. Will the energy use on the site be decreased in the future and when? To what level? *(ex: OU-04 will pump and treat groundwater at 400 gal/min for the first 3 yrs, and will decrease then to 150 gal/min for the remaining 10 years, after which the project will be complete. Corresponding kW hrs drop from 1200 to 600/mo during this time)*

8. For previous "specs" questions regarding fuel and electricity use, if questions cannot be answered completely by RPM, may we have permission to discuss such energy needs with your contractor for the site? If so, please list contact information.

9. Are there currently "Green Practices" taking place at your site such as: cleaner equipment (DPFs, DOCs), cleaner fuels (ULSD), alternative fuels (biodiesel), "renewables" (solar, wind), or participation with utility companies to use their green energy options? Please specify.

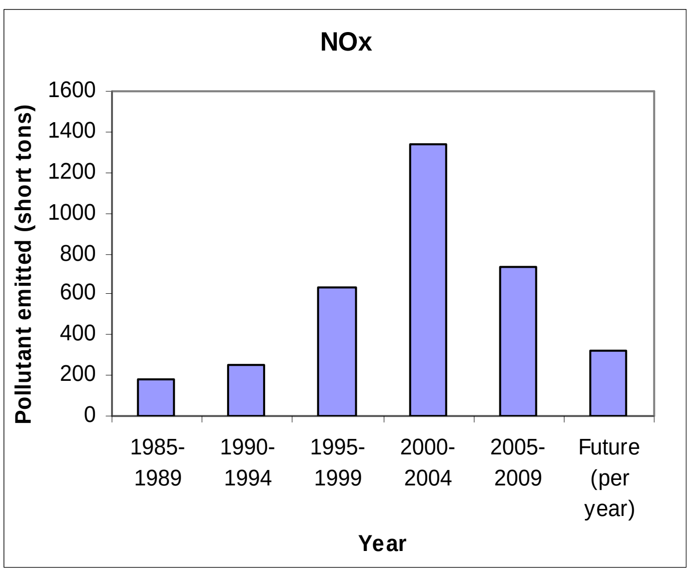
10. Can you list the utility being used at your site for electricity?

Appendix F

Charts and Tables

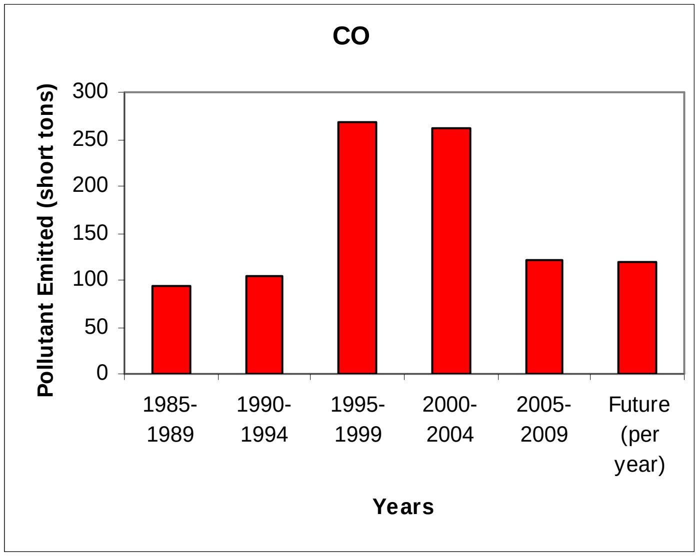
Diesel

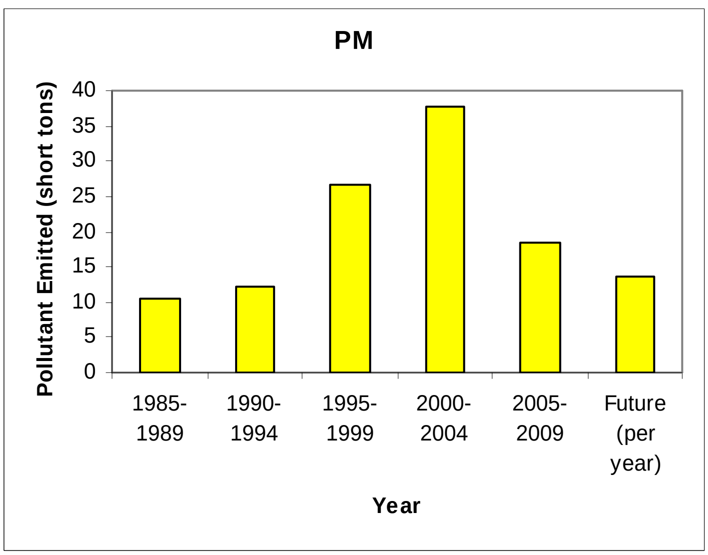
Diesel	Nox(tons)	CO (tons)	PM (tons)
1985-1989	186	93	11
1990-1994	247	104	12
1995-1999	630	268	27
2000-2004	1339	262	38
2005-2009	740	120	18
Future (per year)	325	119	14



Appendix F, (cont.)

Diesel





Appendix F, (cont.)

Electricity

	Total kWH	Total CO2 (tons)	Cars	Homes
1990-1994	73,890,266	36,633	7,193	4,266
1995-2009	176,433,435	83,097	16,317	9,677
2000-2004	262,114,529	115,162	22,613	13,504
2005-2009	481,351,734	193,282	37,953	22,509
Future (per year)	113,177,235	44,611	8,670	5,195

APPENDIX X: UTILITY RATE SCHEDULES

This section provides web addresses to rate schedules for various utilities in Region 9 states and territories. Examine different rate schedules offered by your utility to determine which is optimal for the electricity demands of your site. Also consider demand response rate schedules for remedial activities that do not require a continuous source of power to reduce energy bills. Customers subscribing to this schedule take the risk of utilities shutting off their power during times of peak demand in return for less expensive electricity.

Arizona

Arizona Public Service (APS)

Business: www.aps.com/main/services/business/rates/BusRatePlans_9.html

Residential: www.aps.com/aps_services/residential/rateplans/ResRatePlans_11.html

Salt River Project (SRP)

Business: www.srpnet.com/prices/business/default.aspx

Residential: www.srpnet.com/prices/home/basic.aspx

Tucson Electric Power (TEP)

www.tucsonelectric.com/Business/Programs/pricingplans/tariffs.asp

UniSource Energy Services

http://uesaz.com/Customersvc/PaymentOptions/PricingPlans/tariffs.asp

California

Pacific Gas and Electric Company (PG&E)

http://pge.com/tariffs/ERS.SHTML#ERS

Southern California Edison (SCE)

General Service:

www.sce.com/AboutSCE/Regulatory/tariffbooks/ratespricing/businessrates.htm

Agricultural Pumping:

www.sce.com/AboutSCE/Regulatory/tariffbooks/ratespricing/agriculturerates.htm

San Diego Gas and Electric (SDG&E)

www.sdge.com/regulatory/tariff/current_tariffs.shtml

Commercial and Industrial: www.sdge.com/regulatory/tariff/elec_commercial.shtml

Guam

Guam Power Authority

www.guampowerauthority.com/rates/schedules.html

Nevada

Sierra Pacific Power Company

www.sierrapacific.com/rates/ca/schedules/

Nevada Power Company

www.nevadapower.com/rates/tariffs/schedules/

APPENDIX XI: GREEN PRICING PROGRAMS

Table 13 Utility Green Pricing Programs[367]

State	Utility	Green Pricing Program	Renewable Resource	Price Premiums
AZ	Arizona Public Service	Green Choice Program http://www.aps.com/main/green/choice/choice_7.html	Wind, Geothermal	$1.00 (plus tax) per 100-kWh block in addition to regular bill. Minimum one year commitment.
AZ	Salt River Project	EarthWise www.srpnet.com/environment/earthwise/business.aspx	Solar	$3.00 per 100-kWh block in addition to regular bill.
AZ	Tucson Electric Power Company	GreenWatts www.greenwatts.com/	Solar	$2.00 for 20-kWh, $3.50 for 40-kWh, $5.00 for 60-kWh, $6.50 for 80-kWh, $8.00 for 100-kWh block in addition to regular bill.
AZ	UniSource Energy Services	GreenWatts www.greenwatts.com/	Solar	$2.00 for 20-kWh, $3.50 for 40-kWh, $5.00 for 60-kWh, $6.50 for 80-kWh, $8.00 for 100-kWh block in addition to regular bill.
CA	Anaheim Public Utilities	Green Power www.anaheim.net/utilities/adv_svc_prog/green_power/about_gpower.htm	Various	$1.50 per 100-kWh; $15.00 for 1,000-kWh, $30.00 per 2,000-kWh, or $45.00 per 3,000-kWh block per month. Minimum six month commitment .
CA	Los Angeles Department of Water and Power	Green Power for Green LA www.ladwp.com/ladwp/cms/ladwp000851.jsp	Wind, Landfill Gas	$0.03 per kWh. Minimum 12 month commitment.
CA	PacifiCorp: Pacific Power	Blue Sky www.pacificpower.net/Article/Article35885.html	Wind, Solar, Landfill Gas	$1.95 per 100-kWh increments.
CA	Pacific Gas and Electric (PG&E)	Climate Smart www.pge.com/myhome/environment/whatyoucando/climatesmart/	Forest Conservation, Biomass Projects	$0.0025 per kWh used each month.

CA	Palo Alto Utilities	Palo Alto Green www.cityofpaloalto.org/forms/pagreenenrollment/	Wind, Solar	$0.015 per kWh.
CA	Pasadena Water and Power	Green Power Program www.ci.pasadena.ca.us/waterandpower/greenpower/default.asp	Wind	$25.00 per 1,000-kWh block or All Green Program of $0.025 per kWh used each month.
CA	Roseville Electric	Green Roseville www.roseville.ca.us/electric/green_roseville	Wind, Solar	$0.015 extra per kWh used each month or $15.00 per 1,000-kWh block.
CA	Sacramento Municipal Utility District	Greenergy www.smud.org/community-environment/greenergy/index.html	Wind, Biomass	$0.01 per kWh used each month or $10.00 per 1,000-kWh block (one year commitment for later option).
CA	Silicon Valley Power partnering with 3 Phases	Santa Clara Green Power www.siliconvalleypower.com/green	Solar, Sind	$0.015 per kWh used each month or $15.00 per 1,000-kWh block.
HI	Hawaiian Electric Company, Inc.	Sun Power for Schools www.heco.com/portal/site/heco/menuitem.508576f78baa14340b4c0610c510b1ca/?vgnextoid=b9a85e658e0fc010VgnVCM1000008119fea9RCRD&vgnextchannel=529bf2b154da9010VgnVCM10000053011bacRCRD&vgnextfmt=default&vgnextrefresh=1&level=0&ct=article	Solar	Monthly donation to support PV on Hawaii school buildings.
NV	Nevada Power	Green Power Program www.nevadapower.com/comenv/env/greenpower/	Solar	Monthly tax-deductible donations will be invested in solar education and the construction of solar electric generation facilities at schools in Nevada.

APPENDIX XII: NET METERING PROGRAMS

Net metering programs allow grid-tied utility customers who generate electricity in excess of their consumption at a certain time to "bank" their energy and use it at another time. This is also called net excess generation (NEG). Net metering programs help reduce the payback time for a renewable energy project. Not all utilities offer net metering. The following data on net metering programs were adapted from the Database of State Incentives for Renewables and Efficiency (www.dsireusa.org) and Interstate Renewable Energy Council (http://www.irecusa.org/fileadmin/user_upload/ConnectDocs/NM_table.pdf). Contact the local utility for more information on your local net metering program. For more information, see www.eere.energy.gov/greenpower/markets/netmetering.shtml.

Arizona

Arizona Public Service (APS)

Applicable Sectors: All customers
Applicable Technologies: Solar, Wind, Biomass
Maximum Customer System Size: 100 kW
Maximum enrollment: 15 MW

Any customer NEG will be carried over to the customer's next bill at the utility's retail rate, as a kWh credit. For customers taking service under a time-of-use rate, off-peak generation will be credited against off-peak consumption, and on-peak generation will be credited against on-peak consumption. The customer's monthly bill is based on the net on-peak kWh and net off-peak kWh amounts. Any monthly customer NEG will be carried over to the customer's next bill as an off-peak or on-peak kWh credit. Any NEG remaining at the customer's last monthly bill in a calendar year or at the time of a customer shut-off will be granted to the utility.

Though different from net metering, a July 1981 decision by the Arizona Corporation Commission allows net billing at the utility's avoided-cost rate. APS allows net billing.

APS
428 E. Thunderbird Road #749
Phoenix, AZ 85022
Phone: (602) 216-0318
www.aps.com

Salt River Project

Applicable Sectors: Residential
Applicable Technologies: PV
Maximum Customer System Size: 10 kW
Maximum enrollment: none

For each billing cycle, the kWh delivered to SRP are subtracted from the kWh delivered from SRP for each billing cycle. If the kWh calculation is net positive for the billing cycle, SRP will bill the net kWh to the customer under the applicable price plan, Standard Price Plan E-23 or E-26. If the kWh calculation is net negative for the billing cycle, SRP will credit the net kWh from the customer at an average market price. Net negative kWh will not be transferred to subsequent months.

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Tucson Electric Power Company (TEP)

Applicable Sectors: Commercial, Residential
Applicable Technologies: PV, Wind
Maximum Customer System Size: 10 kW
Maximum enrollment: 500 kW

TEP credits NEG to the following month's bill. After each January billing cycle, any remaining credit is granted to the utility. Installations must meet the IEEE-929 standard, local requirements and National Electrical Code requirements. Installations must be completed within six months of pre-installation approval. Time-of-use net metering is not permitted.

Though different from net metering, a July 1981 decision by the Arizona Corporation Commission allows net billing at the utility's avoided-cost rate. TEP allows net billing.

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California

All Utilities

Applicable Sectors: All customers of all utilities
Applicable Technologies: PV, Wind; Investor owned utilities: PV, Wind, Biogas and Fuel Cells
Maximum Customer System Size: 1 MW
Maximum enrollment: 2.5 percent of each utility's peak demand

NEG is carried forward to a customer's next bill for up to 12 months. Any NEG remaining at the end of each 12-month period is granted to the customer's utility. Customers subject to time-of-use rates are entitled to deliver electricity back to the system for the same time-of-use price that they pay for power purchases. However, time-of-use customers who choose to net meter must pay for the metering equipment capable of making such measurements. Customer-generators retain ownership of all renewable-energy credits associated with the generation of electricity.

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Hawaii

All Utilities

Applicable Sectors: Residential, Small Commercial (including government)
Applicable Technologies: Solar, Wind, Biomass, Hydroelectric
Maximum Customer System Size: 50 kW
Maximum enrollment: 0.5 percent of each utility's peak demand

A customer whose system produces more electricity than the customer consumes during the month may carry forward NEG in the form of a kWh credit that is applied to the next month's bill. Excess credits can be carried over for a maximum of 12 months. At the end of the 12-month reconciliation period, NEG credits will be granted to the utility without customer compensation unless the customer enters into a purchase agreement with the utility.

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http://hawaii.gov/dbedt/info/energy/

Nevada

Investor-Owned Utilities

Applicable Sectors: Commercial, Industrial, Residential
Applicable Technologies: Solar, Wind, Biomass, Hydroelectric, Geothermal
Maximum Customer System Size: 1 MW (utilities may impose fees on systems greater than 100 kW)
Maximum enrollment: 1 percent of each utility's peak capacity

For all net-metered systems, customer NEG is carried over to the following month as a kWh credit, without expiration. If a customer is billed for electricity under a time-of-use schedule, any customer NEG during a given month will be carried forward to the same time-of-use period as the time-of-use period in which it was generated, unless the subsequent billing period lacks a corresponding time-of-use period. If there is no corresponding time-of-use period, then the NEG carried forward must be apportioned evenly among the available time-of-use periods. Excess generation fed to the grid is considered electricity generated or acquired by the utility to comply with Nevada's energy portfolio standard.

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