EIA Technical Review Guidelines: Energy Generation and Transmission

Volume II - Appendices

Regional Document prepared under CAFTA DR Environmental Cooperation Program to Strengthen Environmental Impact Assessment (EIA) Review

Prepared by CAFTA-DR and U.S. EPA Country EIA and Energy Experts with support from:

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This document is the result of a regional collaboration under the environmental cooperation agreements undertaken as part of the Central America and Dominican Republic Free Trade Agreements with the United States. Regional experts participated in the preparation of this document, however, the guidelines do not necessarily represent the policies, practices or requirements of their governments and organizations.

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EIA Technical Review Guidelines: Energy Generation and Transmission

Volume II Appendices

The EIA Technical Review Guidelines for Power Generation and Transmission were developed as part of a regional collaboration to better ensure successful identification, avoidance, prevention and/or mitigation of potential adverse impacts and enhancement of potential beneficial impacts of proposed energy projects undergoing review by government officials, non-governmental organizations and the general public throughout the life of the projects. The guidelines are part of a broader program to strengthen environmental impact assessment (EIA) review under environmental cooperation agreements associated with the “CAFTA-DR” free trade agreement between the United States and five countries in Central America and Dominican Republic.

The guidelines were prepared by regional experts from the CAFTA-DR countries and the United States in both the government organizations responsible for the environment and energy and leading academics designated by the respective Ministers supported by the U.S. Agency for International Development (U.S. AID) contract for the Environment and Labor Excellence Program and grant with the Central America Commission for Environment and Development (CCAD). The guidelines draw upon existing materials from within and outside these countries and from international organizations and do not represent the policies, practices or requirements of any one country or organization.

The guidelines are available from U.S. Environmental Protection Agency (U.S. EPA) in English and from the Central American Commission on Environment and Development (CCAD) in Spanish. Volume I contains the guidelines with a glossary and references which track with internationally recognized elements of environmental impact assessment; Volume 2 contains Appendices with detailed information on energy generation and transmission, requirements and standards, and predictive tools; and Volume 1 Part 2 contains example Terms of Reference cross-linked to Volumes 1 and 2 for use by the countries as they prepare their own EIA program requirements.

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APPENDIX A. WHAT IS ENERGY GENERATION AND TRANSMISSION?

1 INTRODUCTION

The purpose of this appendix is to provide the reviewer of an EIA for an energy generation and/or transmission project with the basic information he or she needs to understand the technologies that are used to generate and transmit electrical energy, and thereby understand the potential environmental impacts of those technologies. The appendix is divided into two sections. The first section presents the technologies for generation of electrical energy. The second section presents the technologies for transmission.

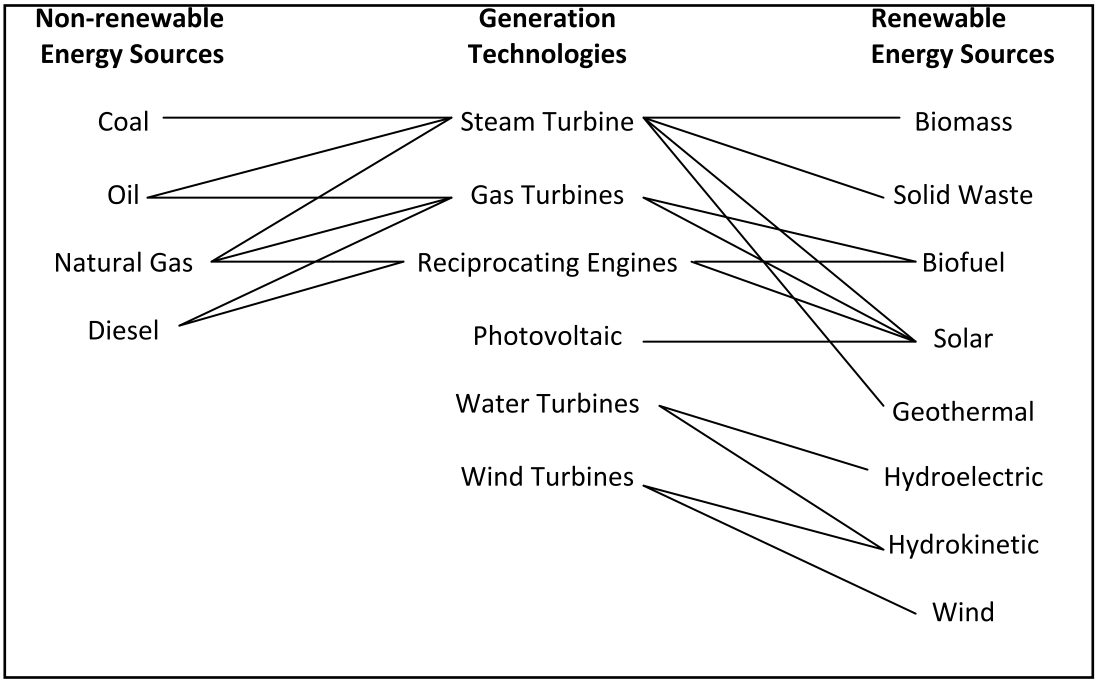
2 ELECTRIC POWER GENERATION

There are many ways to generate electric energy, but they can be broadly divided into two groups, based on the source of the energy used in the system:

- **Non-renewable**, which use fossil fuels (oil, gas, diesel, petrol and coal) that have a limited source and can be depleted, or
- **Renewable**, which use energy sources that can be constantly renewed, and therefore are inexhaustible, such as biomass, biofuels, hydroelectric, hydrokinetic, solar, wind and geothermal.

The technologies used to convert non-renewable and renewable energy into electricity, however, are not always mutually exclusive. Figure A-1 shows how the various sources of renewable and non-renewable energy can be used by generation technologies to produce electrical energy.

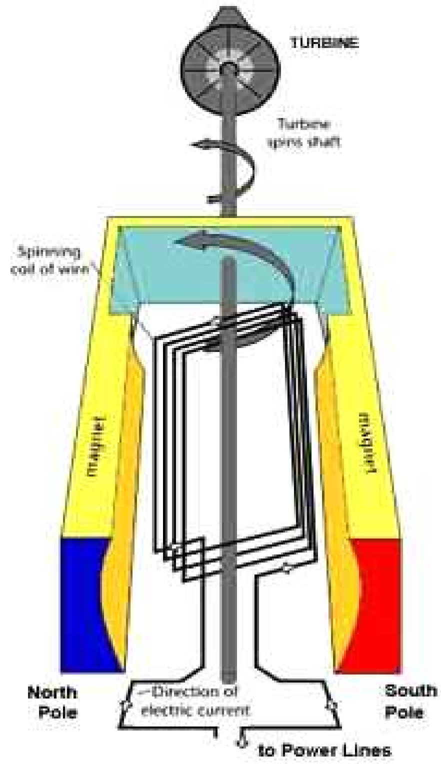
Figure A- 1: Energy sources and generation technologies



As can be seen in Figure A-1, some generation technologies can be powered by several different forms of energy. For instance steam turbines are typically powered by two non-renewable resources (coal and oil) and four renewable resources (biomass, solid waste, solar power and geothermal energy). Other technologies are associated with only one or two forms of renewable energy such as photovoltaic (solar power) and water turbines (hydroelectric and hydrokinetic energy) and wind (wind and hydrokinetic energy). No generating technologies are exclusively associated with non-renewable energy sources.

With few exceptions[1], commercial or public electrical power is produced by generators. Generators are composed of coils of copper wire (or other conducting material) that spin or rotate between magnets, thus generating an electric current (Figure A-2). Alternatively, the coils may surround a spinning magnet, in which case the generator is called an alternator. In either case, the electrical current is generated using the principle of electromagnetic induction, which states that when an electric conductor is moved through a magnetic field electric current will flow in the conductor. Thus the mechanical energy of a spinning rotor is converted into electric energy.

Figure A- 2: Diagram of a generator



The task of most electrical power generation, then, is to spin the generator. This is done either by turbines or engines. There are four basic types of turbines: steam, gas, hydro and wind. As shown in Figure A-1, steam and gas turbines as well as reciprocating engines can be powered by both renewable and nonrenewable energy sources. Hydro and wind turbines are powered only by renewable energy sources.

This subsection will provide a basic description of each type of generation power plant. It begins with a generic description of the steam turbine, which is the most commonly used energy generation technology for producing commercial or public electrical energy. It is also the one technology that is common to many forms of renewable and non-renewable energy sources. This is followed by a subsection on combustion systems, which includes all sources of energy that are combusted to generate electricity. This is followed by one subsection each on hydropower power, solar power, wind power and geothermal power.

2.1. Steam Turbines

A steam turbine is a mechanical device that extracts thermal energy from pressurized steam and converts it into rotary motion. It has almost completely replaced the reciprocating piston steam engine because of its greater thermal efficiency and higher power to weight ratio. About 80 percent of all electricity generation in the world is by use of steam turbines. Figure A-3 presents a very basic diagram of how a steam turbine works. Although it is simplistic, Figure A-3 clearly presents the basic concept: some form of heat is used to create steam, which is then passed across blades of a turbine causing it to turn, thus rotating a generator and producing electricity. Of course actual designs are quite

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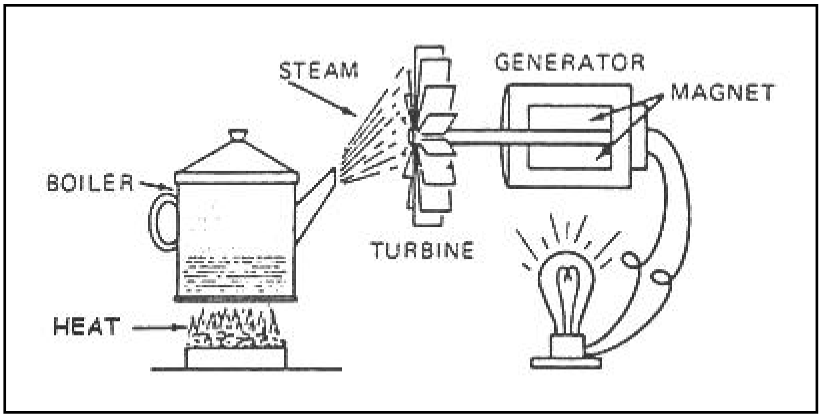
[1] The exceptions to using rotary generators to produce electricity are solar photovoltaic systems and fuel cells. Solar photovoltaic systems are described in this appendix. Fuel cells are not included in these guidelines, as they are not commonly used for commercial electrical power generation.

complicated, with the shape and the size of the turbine as well as the shape and configuration of the blades being specially designed to insure maximum of conversion of the heat and pressure in the steam to electrical energy. For instance, steam expands as it works, so the turbine is wider at the end where the steam exits than it is where it enters.

Figure A- 3: A basic diagram of a steam turbine



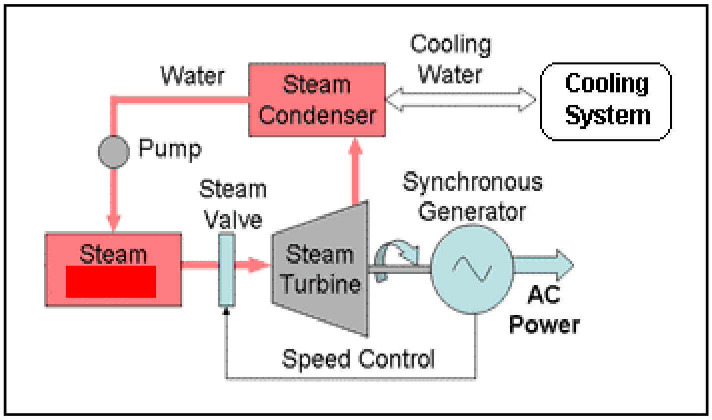
Source: Based on a figure from http://cr4.globalspec.com/comment/641909

2.1.1. *Common System Components*

All power plants that use steam turbines have some common components (Figure A-4). These include:

- A source of water
- A source of steam
- Steam turbines
- Generators
- A steam condenser
- A cooling system

Figure A- 4: Common components of power plant using a steam turbine



Source: Based on a figure from the Electropedia website. http://www.mpoweruk.com/steam_turbines.htm

Steam turbines need water and a means of converting water into steam to operate. The steam can be generated by many different technologies:

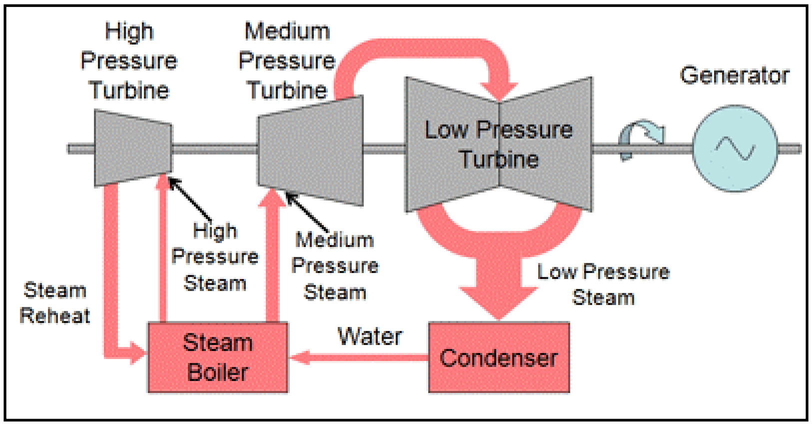
- Combustion of fuel including fossil fuels, biomass, biofuels and solid waste
- Solar power
- Geothermal energy

The specific ways that each of these technologies generates steam are discussed below in the subsections on these technologies.

However the steam is generated, it leaves the steam generator at high temperature (up to 900°C) and high pressure and flows through pipes into the turbine, where it flows across blades causing them to turn and drive a shaft that is connected to the generator. The speed at which the turbine spins can is controlled by the rate at which the steam is allowed to enter the turbine. The rate is controlled by the steam valve, which in turn is controlled by a feedback loop from the generator which allows the system to be set up to turn insure that the generator is turned at an optimal speed to produce electricity.

The energy of the steam decreases as it turns the blades, so that it leaves the turbine at a lower pressure and cooler temperature than when it entered the turbine. Steam turbines can be designed to work at various pressures, and often different pressure turbines are installed in series to take advantage of the decreasing pressure of the steam as it moves through the turbines (Figure A-5).

Figure A- 5: Multi-pressure steam turbines



Source: http://www.mpoweruk.com/steam_turbines.htm

Eventually, the steam has too little energy left to turn a turbine, at which point it is passed to a condenser. The condenser has tubes running through it in which cool water is flowing. The flowing cool water removes the heat from the steam until it condenses back into water and flows or is pumped back to the steam generator to be used again. The condenser cools the steam to the point where it has zero volume (i.e., it has moved back into a liquid phase). This creates near vacuum conditions in the condenser, which further "sucks" steam through the low pressure turbine, enabling the maximum amount of energy to be extracted from the steam and converted into electrical energy.

At some industrial and commercial facilities that have their own power plants, the "spent" steam may be used for heating or other uses, thus eliminating the need for a condenser. But this is not a common practice at power plants.

2.1.2. Cooling Systems

The water used in the condenser's coils comes from a cooling system. The water in the cooling system is separate from the "working" water in the steam system, although they usually come from the same source. A constant flow of cooling water is required to reduce the temperature of the steam and water in the condenser. The heat carried away from the condenser is waste heat, and usually accounts for about 50 percent of the total heat energy that is emitted from the steam generator (the other 50 percent being converted into mechanical energy inside the turbines). Steam turbine electric plants use either once-through cooling water systems or recirculating cooling water systems.

2.1.2.1. Once-Through Cooling

In once-through cooling water systems, the cooling water is withdrawn from a body of water, flows through the condenser, and is discharged back to the body of water (Figure A-6). Once-through systems require a significant amount of water for cooling. For example, a 200 MW coal-fired plant can require up to 480,000 m^3 per day of cooling water (Table A-1). If that water is supplied via a once-through system, then that full amount of water is needed each day. If, on the other hand, the cooling water is reused after being cooled by a pond or a tower, the amount of water needed each day can drop to 15,000 m^3. However, once-through systems consume less water. That is because the cooling water is generally not raised to evaporative temperatures in the cooling system, so that almost 100 percent of the withdrawn for cooling is discharged back into the source. At a typical coal-fired 200 MW plant with a once-through cooling system may only consume 1,000 m^3 per day of cooling water, or less than 0.2 percent of the water withdrawn. The same size facility using a cooling pond or cooling tower may only use 15,000 m^3 per day of cooling water, but will consume nearly all of it (14,000 m^3) due to evaporation.

Figure A- 6: Once-through cooling system diagram

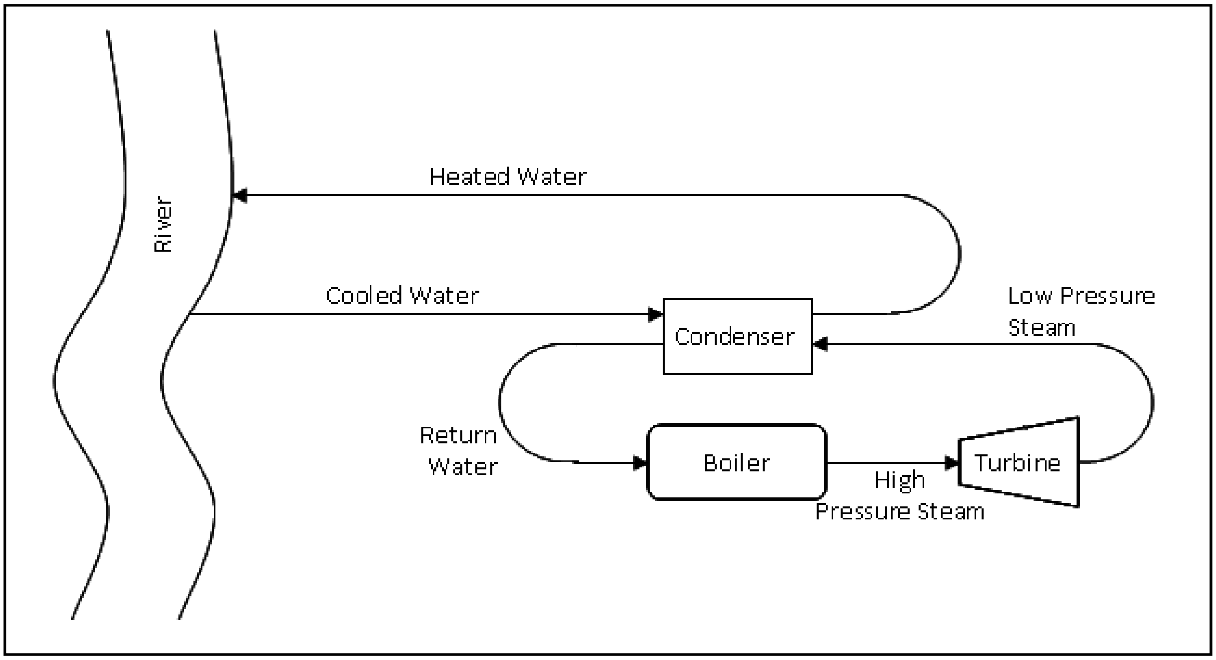


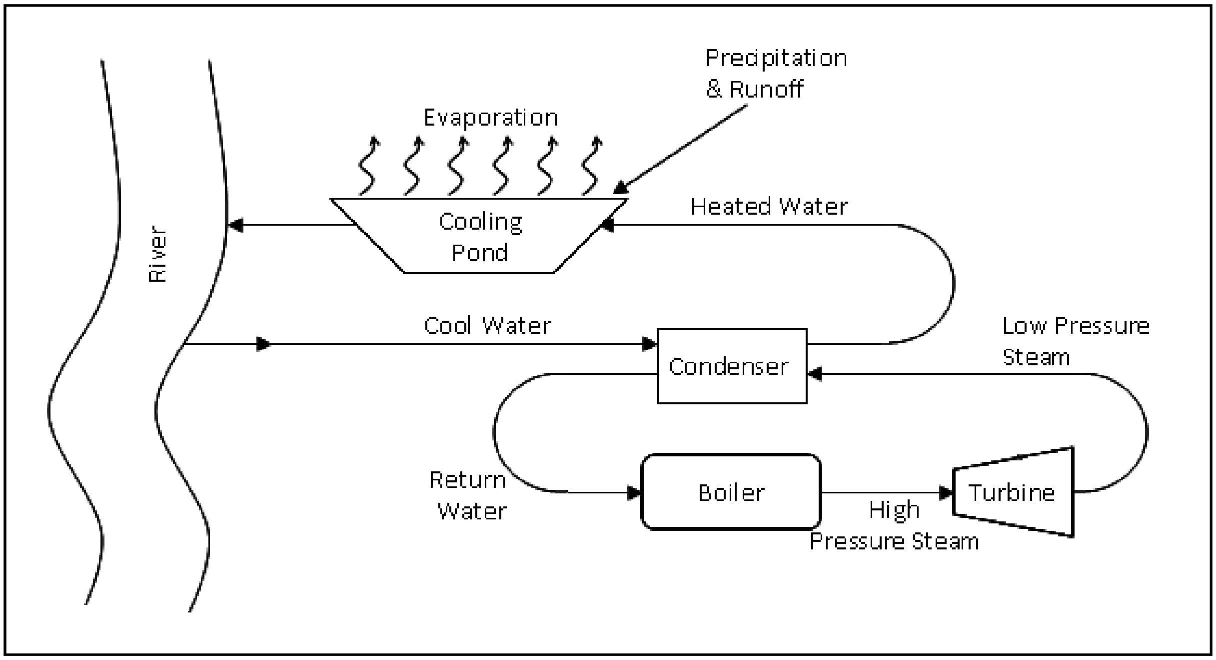
Table A- 1: Average cooling system water use and consumption at a coal-fired thermal plant

Type of Cooling Water System	Water Use		Water Consumption	
	Average (m^3/MWh)	200MW Plant (1,000 m^3/day)	Average m^3/MWh	200MW Plant (1,000 m^3/day)
Once-Through	142.7	480	0.4	1
Recirculating Wet	4.5	15	4.2	14

Source: Average water use from Feeley 2005.
http://204.154.137.14/technologies/coalpower/ewr/pubs/IEP_Power_Plant_Water_R&D_Final_1.pdf.
Average capacity factor for coal plant from U.S. DOE 2010.
http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html

Although once-through systems consume very little water, they require large amounts, and the water they discharge back into the environment is at elevated temperatures, which can have a significant impact on aquatic ecosystems if the quantity of discharged water exceeds the receiving water's capacity to dilute the temperature to an acceptable level. Some once-through designs use cooling ponds at the end of the cooling system to allow the water to cool to an acceptable level before being discharged back to the source (Figure A-7). Another practice which has had some use in the United States is to build constructed wetlands to receive cooling water and provide additional cooling before returning water to the source. Constructed wetlands are not as deep as a cooling pond, so more land is needed to treat the same volume of water. These systems loose more water to evaporation (one of the primary cooling mechanisms in the ponds and wetlands) than a simple once-through system, however, rainwater runoff and direct precipitation will compensate for part of the evaporation losses.

Figure A- 7: Once-through cooling system with cooling pond diagram



2.1.2.2. Recirculating Cooling

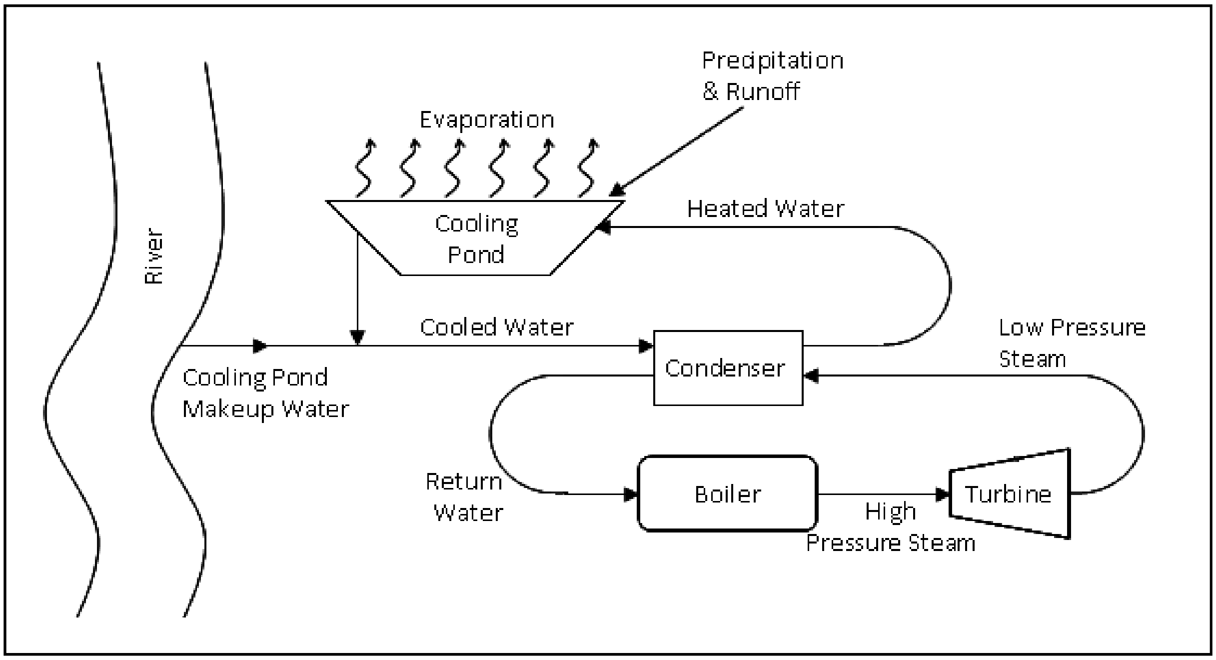
In a recirculating cooling system the water that passes through the condenser is sent to a cooling pond or cooling tower to lower its temperature so that it can be reused in the cooling system. At some plants both ponds and towers are incorporated into the cooling system. Recirculating cooling systems can be divided into two groups: wet cooling, which relies upon evaporation for cooling, and dry systems, that use air too cool the turbine steam or cooling water.

Wet Cooling

Wet cooling systems may use either cooling towers or cooling ponds to reduce the temperature of the cooling water before it is recirculated through the condenser. Ponds are generally less expensive as they do not required extensive construction and maintenance and generally require lower pumping costs. Ponds can also create secondary recreational uses such as fishing, swimming, boating, camping and picnicking and can also been used as fish hatcheries. Ponds, however, require much more space than towers.

In a recirculating cooling pond system, cooling water is drawn from and discharged to the cooling pond (Figure A-8). Water in the pond will evaporate, as one of the key cooling mechanisms. The evaporation will be somewhat compensated by rainwater runoff and direct precipitation, but make up water will have to be withdrawn from the source to compensate for the remainder of evaporation. If the site hydrology is favorable, the evaporation losses from the cooling pond could be balanced by rainwater harvesting, making the cooling pond a “closed system,” needing no water from the source. In this way, pond recirculating systems often consume less water than tower systems.

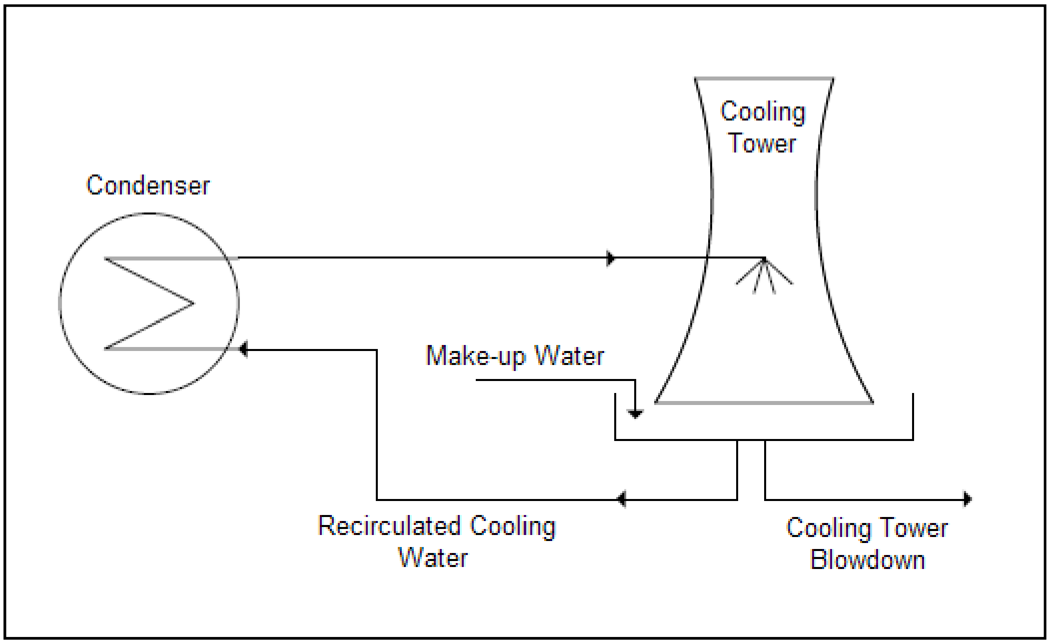
Figure A- 8: Recirculating cooling system with cooling pond diagram



The size of the pond will depend upon the size of the power plant, in that it must be large enough to provide adequate cooling water during periods of peak production. Depending on the design, it may also be quite deep, because deep water tends to stay cooler longer.

In a cooling tower, the heated water from the condenser enters at the top and falls down through a fill material with a high surface area that interrupts the flow of the water (Figure A-9). Depending on the design of the fill material, the water will either splash or trickle through the tower. In either case, as water flows downward, air flows upward through the tower, causing some of the water to evaporate. As water evaporates, the heat required to evaporate the water is transferred from the water to the air, thus cooling the water. The water that does not evaporate is collected at the bottom of the tower and pumped back to the condenser. In the process, however, water is lost via evaporation, so that additional fresh water must be periodically added to the cooling system.

Figure A- 9: Cooling tower diagram



Source: U.S. EPA 2009, Table 3-4.
http://www.epa.gov/waterscience/guide/steam/finalreport.pdf

As cooling water evaporates in the cooling tower dissolved minerals present in the water remain behind in the fill material and on the inside of the tower walls. Over time, these minerals will increase in concentration and can inhibit the effectiveness of the tower. To prevent a build of minerals, a volume of water must be discharged periodically to purge the minerals from the system, which is referred to as "cooling tower blowdown."

Cooling towers be hyperboloid or rectangular structures. Hyperboloid structures can be larger than rectangular structures, up to 200 meters tall and 100 meters in diameter. Rectangular structures can be over 40 meters tall and 80 meters long.

Cooling towers use two mechanisms to draw air up through the water: natural draft and mechanical draft. Some plants combine natural and mechanical components in a fan assisted natural draft.

Natural draft towers rely on the difference in air density between the warm air in the tower and the cooler ambient air outside the tower to draw the air up through the tower. Hyperboloid cooling towers (as shown in Figure A-9) have become the design standard for natural draft cooling towers because of their structural strength and minimum usage of material and because their shape aids in accelerating the upward convective air flow.

Mechanical draft towers utilize fans to move air up through the tower. They may be hyperboloid or rectangular structures. The fans may be used to create an induced draft with fans at the discharge to pull air through tower, or a forced draft with a blower type fan at the intake pushing air up through the tower. Forced draft design has some technical drawbacks as well as usually requiring bigger fans, so they are less common than induced draft towers.

Dry Cooling

Dry cooling towers are essentially large radiators hot water flowing down through the tower through multiple layers of relatively small diameter, finned pipes. Air is passed up through these pipes by large fans at the top or bottom of the tower (depending on the design), thus cooling the water before it is used again. Dry cooling towers are usually rectangular or A-frame in shape.

Dry cooling towers can either use direct or indirect cooling. In direct cooling systems, the turbine exhaust steam flows directly to the tower, where it is cooled and reused in the boiler (Figure A-10). In an indirect cooling system the hot cooling water flowing out of the condenser is pumped up to the top of the tower, where it flows down through the tower, cooling on its way, and then is used again in the condenser (Figure A-11).

Figure A- 10: Dry cooling tower diagram for direct cooling

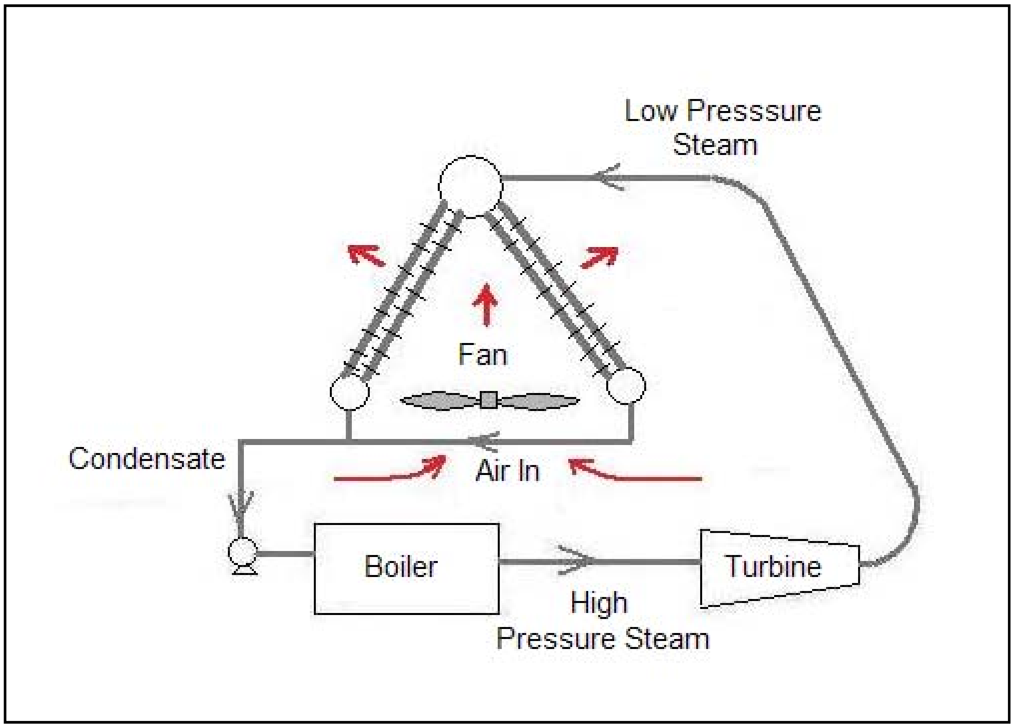
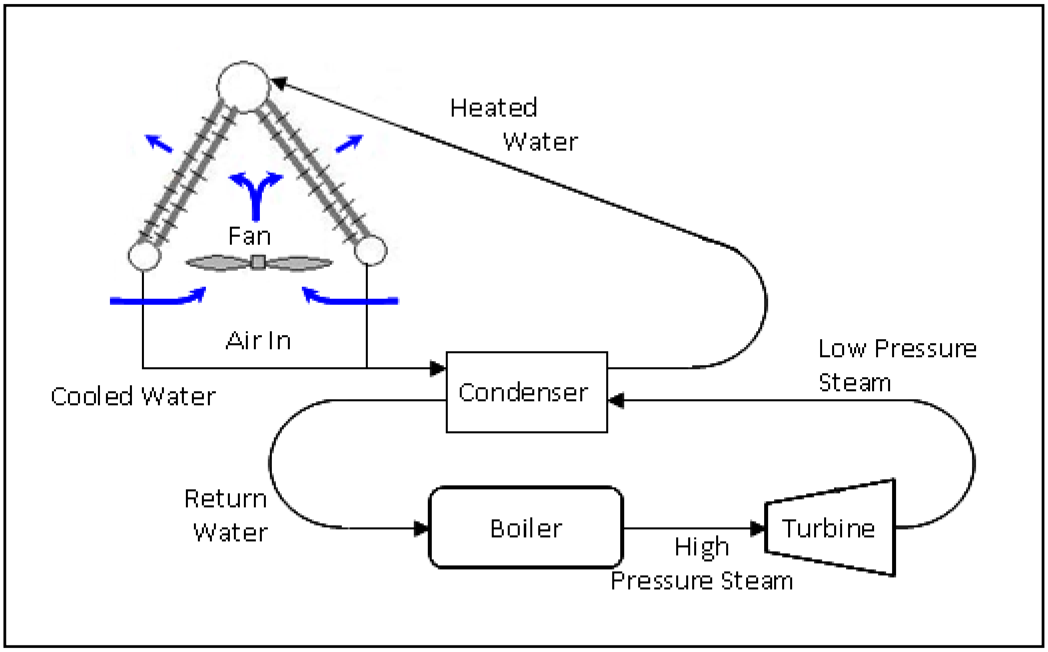


Figure A- 11: Dry cooling tower diagram for indirect cooling



Dry cooling is the most expensive form of cooling (Table A-2), but it may be necessary in areas where there is a water shortage or other limitation on water availability. Because dry cooling systems transfer heat to the atmosphere without water evaporation, they use very little water.

Table A- 2: Relative costs of cooling systems

Item	Type of Cooling System		
	Once-Through	Wet Tower	Dry Cooling
Capital Cost	Base	Base + 0.4%	Base + 12.5
Cooling System Power (major component of operating costs)	Base	Base + 2.5 MW	Base + 3.0 MW
Power Production Cost	Base	Base + 1.9%	Base + 4.9%

Source: Bengtson 2010

2.1.2.3. Discharges

In addition to minerals that accumulate on the fill material and are periodically removed with blowdown, cooling water may contain other chemicals associated with cooling water treatment. As the cooling water passes through the condenser, microbiological species (e.g., bacterial slimes and algae) stick to and begin growing on the condenser tubes, which reduces heat transfer, decreases flow, and accelerates corrosion of the condenser. Various macro-organisms, such as mussels, mollusks, and clams, can also inhibit condenser performance. Steam electric plants use biocides, such as sodium hypochlorite, sodium bromide, chlorine gas and antimicrobials to control these biological problems.

As a result, once-through cooling water and cooling tower blowdown may contain the following pollutants, often in low concentrations: chlorine, iron, copper, nickel, aluminum, boron, chlorinated organic compounds, suspended solids, brominated compounds, and nonoxidizing biocides. Although the pollutants present in cooling water-related wastewaters are often at low concentrations, the overall pollutant mass discharge may be significant due to the large flow rates of cooling water discharges at steam electric power plants.

2.2. Combustion Power Plants

In these guidelines, the term combustion or thermal/combustion power plants is used to refer to all power plants that use the combustion of fuels to either directly or indirectly turn generators or alternators that produce electrical energy. The fuels may be non-renewable (coal, oil, natural gas, or diesel) or renewable (biomass, solid waste, or biofuel).

The fuels are combusted to power three different types of electrical power generating technologies: steam turbines, gas turbines and reciprocating engines. Each technology has its own unique design characteristics and components, which are described in the following subsections. The technologies can be divided into two groups: external and internal combustion. External combustion means that combustion of the fuel is external to the machinery that turns the generator or alternator to produce electricity. Steam turbines rely upon external combustion. Internal combustion means that the fuel is combusted internal to the engine, as in a confined chamber or cylinder and that the energy of the combustion is directly converted into mechanical action that turns generators or alternators. Gas turbines and reciprocating engines are internal combustion engines.

Fossil fuels include coal, various types of fuel oil, natural gas and diesel. Gasoline may also be used to fuel generators, but it is generally not used at commercial facilities for this purpose, so it is not discussed in these guidelines. Two major categories of fuel oil are burned for power generation: distillate oils (grade Nos. 1 and 2) and residual oils (grade Nos. 5 and 6). Grade No. 4 oil is either distillate oil or a mixture of distillate and residual oils. No. 6 fuel oil is sometimes referred to as Bunker C.

Biomass and biofuels are a renewable energy source derived from living, or recently living organisms (i.e., not fossilized carbon), such as wood, waste, plants and algae. Biomass is generally considered solid fuel such as fuelwood, charcoal, agricultural crops and by-products, forest residues, industrial wood wastes and solid waste. Biofuels are derived from conversion of biomass (organic material) into a combustible fuel. Biomass can be converted into biofuels via physical extraction (as in the case of some oils), decomposition, fermentation, thermal processes, or chemical processes. Biofuels may be gases such as methane or liquids such as ethanol or biodiesel. Most biofuel production comes from harvesting organic matter and then converting it to fuel but an alternative approach relies on the fact that some algae naturally produce ethanol and this can be collected without killing the algae.

2.2.1 *Fuel Storage*

Different fuels have different storage needs. Solid fuels such as coal and biomass are generally stored in piles. Runoff from the piles in the case of coal will contain pollutants, and biomass piles may also generate pollutants in the runoff, so both types of piles need to have run-on and runoff control structures. Coal piles may also need to be covered to prevent runoff caused by rainfall.

Liquid fuels need to be stored on-site in tanks. The tanks need to be placed on impervious containment structures to prevent contamination from leaks and spills. Natural gas is generally piped into a facility, thus requiring no storage.

If biofuels are to be used, they may be generated off site and transported to the site or generated on-site. Generation may involve digesters, fermenters and distillers.

Some fuels, like coal, heavy oil and biomass, create ash during combustion. Facilities are required for handling and disposing of these wastes.

2.2.2 *Air Emission Controls*

Combustion power plants all emit exhausts that can be significant sources of air emissions with the potential for significant impacts to ambient air quality. They will nearly always include post-combustion emission control devices to control emissions of PM, SO_2, NO_X and CO_2.

Post-combustion control of PM emissions from coal-, biomass- and oil-fired plants can be accomplished by using one or more or the following particulate control devices:

- Electrostatic precipitators (ESPs) are commonly used in coal- and oil-fired power plants. Because of their modular design, ESPs can be applied to a wide range of system sizes.
- Fabric filter (or baghouse), a number of filtering elements (bags) along with a bag cleaning system are contained in a main shell structure incorporating dust hoppers.
- Wet scrubber, including Venturi and flooded disc scrubbers, tray or tower units, turbulent contact absorbers, or high-pressure spray impingement scrubbers. They are applicable for PM as well as SO_2 control on oil-, coal- and biomass fired plants.
- Cyclone separators can be installed singly, in series, or grouped as in a multicyclone or multiclone collector. These devices are referred to as mechanical collectors and are often used as a pre-collector upstream of an ESP, fabric filter, or wet scrubber so that these devices can be specified for lower particle loadings to reduce capital and/or operating costs. Although these devices will reduce PM emissions from coal combustion, they are relatively ineffective for collection of particles less than 10 micron (PM10). In oil-fired plants, cyclones are primarily useful in controlling particulate matter generated during soot blowing, during upset conditions, or when very dirty heavy oil is fired.
- Side stream separators combine multicyclones and a small pulse-jet baghouses to more efficiently collect small-diameter particles that are difficult to capture by a mechanical collector alone. Most applications to date for side-stream separators have been on small stoker coal-fired boilers. Atmospheric fluidized bed combustion (AFBC) coal-fired boilers may tax conventional particulate control systems.

Flue gas desulfurization (FGD) is the post-combustion control technology for SO_2 emissions from fossil fuel-fired power plants. It uses an alkaline reagent to absorb SO_2 in the flue gas and produce a sodium or calcium sulfate compound. These solid sulfate compounds are then removed in downstream equipment. FGD technologies are categorized as wet, semi-dry, or dry depending on the state of the reagent as it leaves the absorber vessel. These processes are either regenerable (such that the reagent material can be treated and reused) or non-regenerable (in which case all waste streams are de-watered and discarded).

Post-combustion control of NO_X emissions are:

- Selective non-catalytic reduction (SNCR), which involves injecting ammonia (NH_3) or urea into specific temperature zones in the upper furnace or convective pass. The NH_3 or urea reacts with NO_X in the flue gas to produce nitrogen, CO_2 and water.
- Selective catalytic reduction (SCR), which is an add-on NO_X control placed in the exhaust stream following the engine and involves injecting NH_3 into the flue gas. The NH_3 reacts with the NO_X in

the presence of a catalyst to form water and nitrogen. The SCR reactor can be located at various positions in the process including before an air heater and particulate control device, or downstream of the air heater, particulate control device, and flue gas desulfurization systems.

Carbon capture may involve either pre-combustion or post-combustion separation of CO_2 from emission sources. Pre-combustion CO_2 capture typically involves gasification processes, such as integrated gasification combined cycle (IGCC) technology, where coal or biomass is converted into gaseous components by applying heat under pressure in the presence of steam. IGCC plants may be designed so that concentrated CO_2 at a high pressure can be captured from the synthesis gas that emerges from the gasification reactor before it is mixed with air in a combustion turbine. Because CO_2 is present at much higher concentrations in synthesis gas than in post-combustion flue gas, IGCC systems currently appear to be the economic choice for new plants.

Post-combustion CO_2 capture involves physical and chemical processes to separate CO_2 from the exhaust flue gas. These systems might be applicable to retrofits of conventional coal or biomass energy plants, and also might be applicable to other thermal/combustion energy production technologies. However, such systems are challenging and, currently, costly because the low pressure and dilute CO_2 concentrations dictate a high actual volume of gas to be treated. Further, trace impurities in the flue gas tend to reduce the effectiveness of the CO_2 adsorbing processes, and compressing captured CO_2 from atmospheric pressure to pipeline pressure represents a large parasitic load. One technological option, oxygen combustion (oxy-combustion), combusts coal in an enriched oxygen environment using pure oxygen diluted with recycled CO_2 or water. This process enables a relatively concentrated stream of CO_2 to be captured by condensing the water in the exhaust stream. Oxy-combustion offers several potential benefits for existing coal- and biomass-fired plants.

After the CO_2 emissions have been collected/captured, the CO_2 must be sequestered (immobilized or removed), either geologically (e.g., saline aquifers) or via enhanced oil recovery. In the U.S., significant research is ongoing to demonstrate the feasibility of geologic sequestration in saline aquifers and to overcome implementation barriers, such as concerns about safety, effectiveness, liability, and public acceptance.

Another potential type of CO_2 sequestration is CO_2-enhanced oil recovery, a commercially proven technology that has been used extensively in the United States to increase oil production at diminished wells. In CO_2-enhanced oil recovery, compressed CO_2 is injected into an oil reservoir near the production well site, forcing the oil toward the production well and increasing yield. Several planned IGCC plants in the U.S. expect to derive a substantial economic benefit through the sale of their CO_2 for CO_2-enhanced oil recovery.

2.2.3 *Combustion Power Plants Using Steam Turbines*

Combustion steam turbine power plants may be fueled by coal, oil, natural gas, biomass and biofuel. Biomass fuels for these types of plants are most often wood, hemp, miscanthus, crop or agricultural production by-products (straw, field residues, rice husks, corn cobs, bagasse[2], etc.) and solid waste. At least one combustion steam turbine plant in the CAFTA-DR region, the Monte Rosa plant in Nicaragua, burns biogas made from vinasse, the still bottoms left after distillation of fermented sugarcane. The fuel is combusted in a combustion chamber. The heat energy generated by the combustion of fuel is transformed into electrical energy indirectly, usually by means of heating boilers or boiler tubes to

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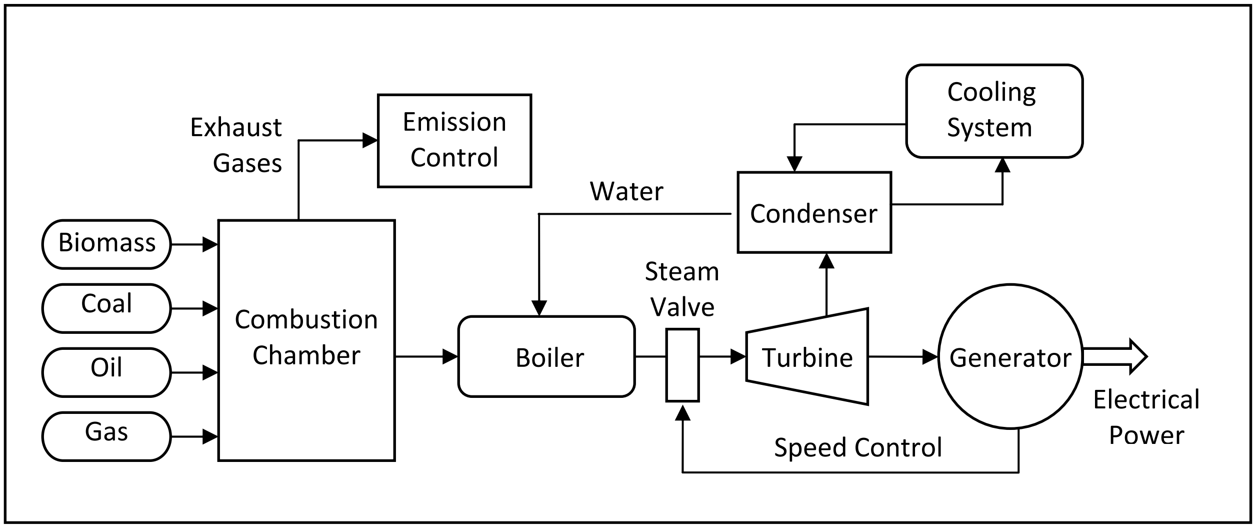
[2] The fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice.

generate steam. The resulting steam is then used to power steam turbines or engines that turn generators or alternators, thus creating electrical energy. A diagram of a combustion steam turbine plant is shown in Figure A-12.

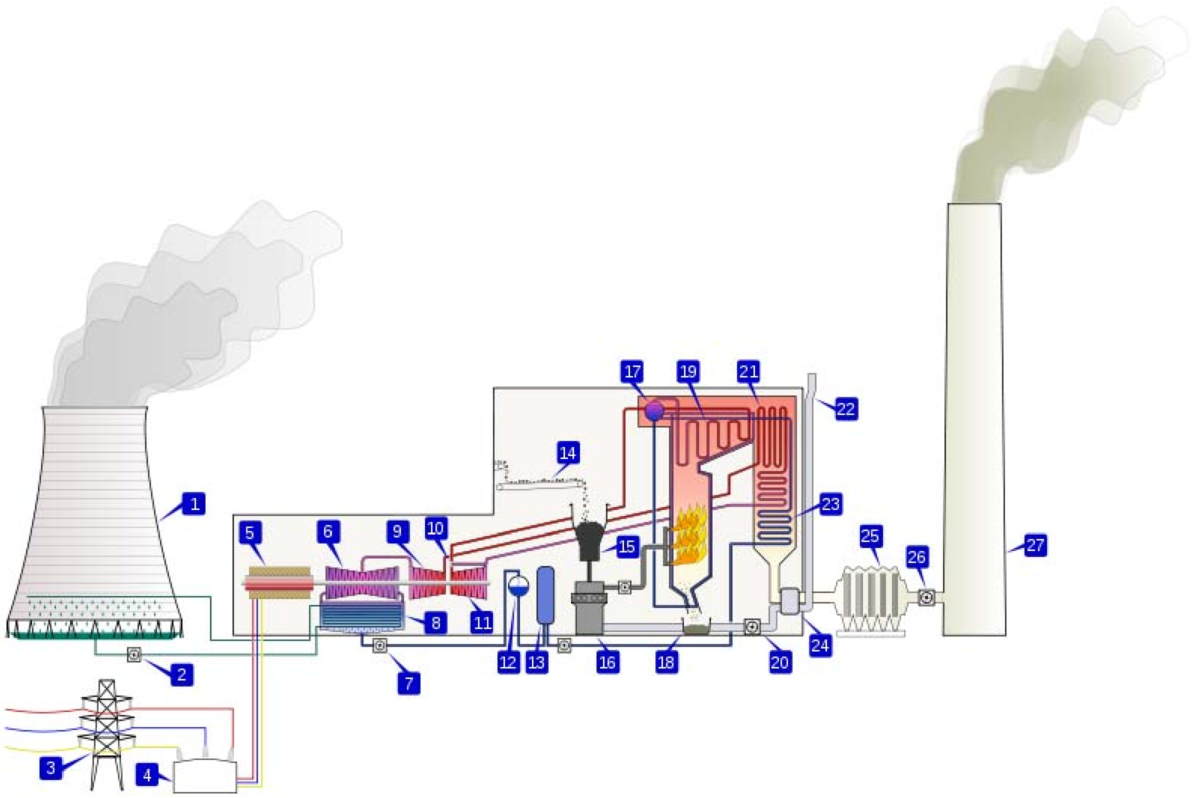
Figure A- 12: Combustion steam turbine plant diagram



All of the components of a combustion steam turbine plant to the right of the boiler have been previously described in subsection 2.1 Steam Turbines. These components are common to any steam turbine system. Fuel storage and air emission controls, which are common to all combustion power plants, are discussed in subsections 2.2.1. and 2.2.2. This section, therefore, focuses on the combustion chamber, boiler and ancillary equipment.

A more detailed diagram of a combustion steam turbine power plant is presented Figure A-13. Although this diagram is for a coal powered plant, the basic components are similar for any thermal/combustion steam turbine plant. The key differences among thermal/combustion steam turbine plants are due to differences in fuel and combustion waste by products, so that components 14 through 16 and 18 in the diagram may be different for different types of fuels.

Figure A- 13: Coal-fired thermal power plant diagram



1. Cooling system
2. Cooling water pump
3. Transmission line
4. Step-up transformer
5. Electrical generator
6. Low pressure steam turbine
7. Condensate pump
8. Surface condenser
9. Intermediate pressure steam turbine
10. Steam Control valve
11. High pressure steam turbine
12. Deaerator
13. Feedwater heater
14. Coal conveyor
15. Coal hopper
16. Coal pulverizer
17. Boiler steam drum
18. Bottom ash hopper
19. Superheater
20. Forced draught (draft) fan
21. Reheater
22. Combustion air intake
23. Economiser
24. Air preheater
25. Emissions control
26. Induced draught (draft) fan
27. Flue gas stack

Source: http://en.wikipedia.org/wiki/Thermal_power_station

The combustion chamber is typically an integral component of the boiler as shown in Figure A-13. It consists of fuel and air inputs as well as a combustion zone. Depending on the design, the fuel and/or air may have some pre-treatment. For example, Figure A-13 includes a coal pulverizer, which crushes the coal before it is introduced to the combustion chamber. Fuel is delivered into the boiler's furnace where it is combusted to heat water in a pressurized vessel in small boilers or in a water-wall tube system in modern utility boilers. Additional elements within or associated with the boiler, such as the superheater, reheater, economizer and air heaters, improve the boiler's efficiency.

Apart from the basic steam raising and electricity generating equipment, there are several essential automatic controls and ancillary systems which are necessary to keep the plant operating safely and at its optimum capacity. These include:

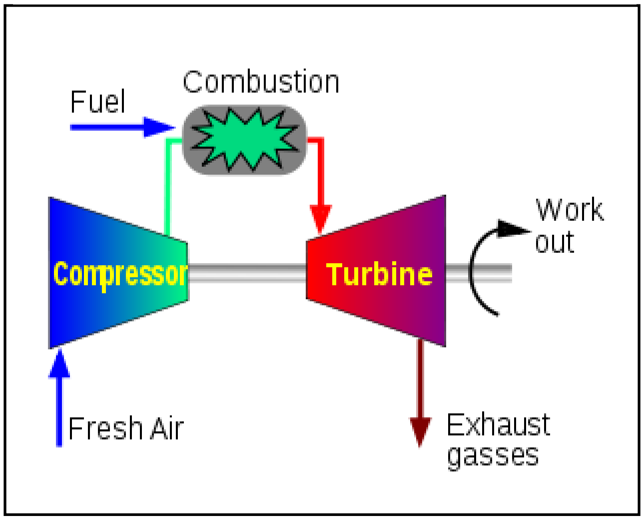
- Controls for:
  - matching the power output to the demand,
  - maintaining the system voltage and frequency, and
  - keeping the plant components within their operating pressure, temperature and speed limits.
- Lubrication systems.
- Systems to prepare and feed the fuel to the combustion chamber and remove the ash.
- Pumps and fans for water and air flow.
- Cooling the generator.
- Overload protection, emergency shut down and load shedding.

2.2.4 *Gas Turbine*

Gas Turbines, also called combustion turbines, extract energy from the flow of combustion gas across turbine blades. They consist of a compressor that compresses air, which is fed into a combustion chamber. Fuel is also introduced into the combustion chamber, where it ignites with the air creating a high pressure, high velocity exhaust gas, which is then directed to the turbine (Figure A-14). They are typically fueled by natural gas or oil, but could potentially be fueled by biofuel (e.g., biodiesel or biogas. They range in size from 500 kW up to 25 MW for distributed electrical power systems and up to 250 MW for central power generation. Gas turbines can provide baseload in a power system. They also have the advantage of the ability to be turned on and off within minutes, making them useful for supplying power during peak demand.

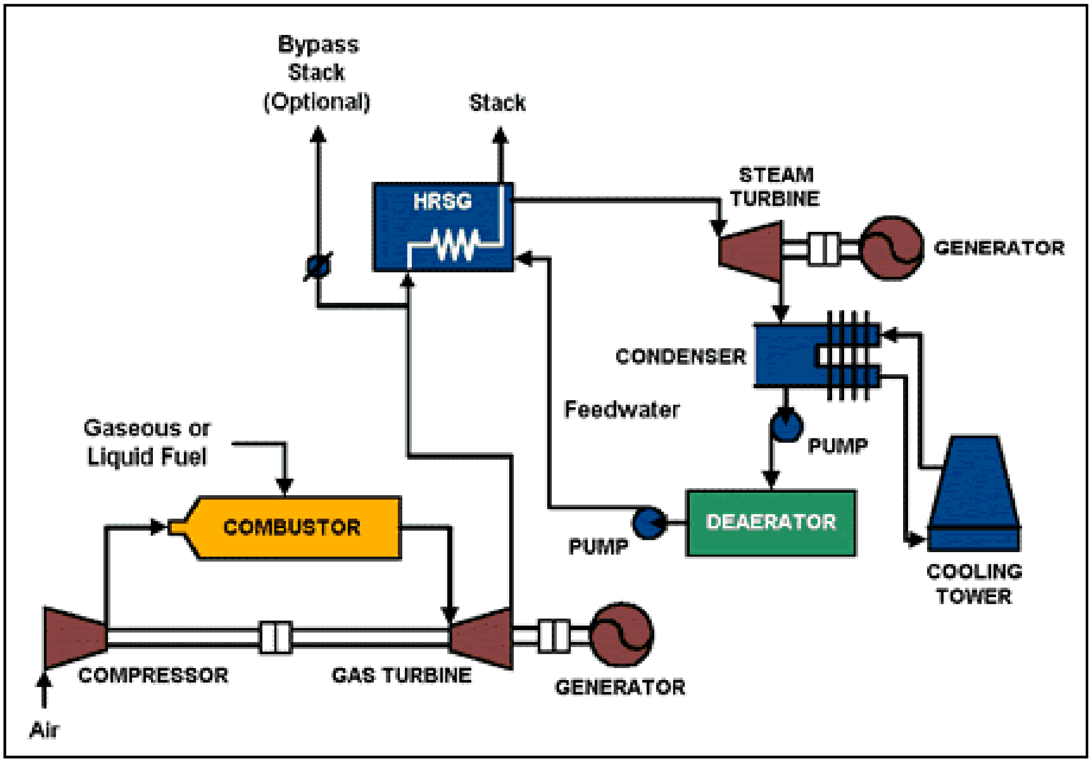
The exhaust gas from a gas turbine is capable of producing high-temperature steam, so many power plants use gas turbines in combination with steam turbines to generate electrical power. These systems are called combined-cycle generating units (Figure A-15). In these units, the exhaust gases from the gas turbines are fed into the heat recovery steam generator (HRSG), also known as a boiler, thus reducing the amount of fuel needed to produce steam and improving the efficiency of electricity generation. Most new gas power plants in North America and Europe are of this type. For large scale power generation a typical set would be a 400 megawatt (MW) Gas Turbine coupled to a 200 MW Steam Turbine giving 600 MW. A typical power station might comprise of between 2 and 6 such sets.

Figure A- 14: Gas turbine diagram



Source: Based on Wikipedia figure.
http://en.wikipedia.org/wiki/Brayton_cycle

Figure A- 15: Combined-cycle generating unit



Source: http://www1.eere.energy.gov/tribalenergy/guide/images/illust_combinedcycle_generating_sys.gif

Micro turbines are small gas turbines fueled by natural gas, diesel and biogas that produce between 25 kW and 500 kW of power. Their designs evolved from automotive and truck turbocharger technologies as well as small jet engines and aircraft auxiliary power units. The earlier models merely released exhaust gases to the environment, but most new models are using recuperating technologies, which recover the heat from the exhaust gases to boost the temperature of the combustion and increase efficiency.

They are still in the development stage for use in electrical power generation, but many micro turbine installations are currently undergoing field tests, including some that are part of large-scale demonstrations. Some are also being tested using landfill gases as the fuel. They may become popular in the future due to their small size, light weight, small number of moving parts, and low emissions.

2.2.5 *Reciprocating Engine Generators*

A reciprocating engine generator is a combination of an internal combustion engine, a generator and various ancillary devices such as base, canopy, sound attenuation, control systems, circuit breakers, jacket water heaters, starting systems etc. Sizes up to about five MW are used for small power stations, which may use up to 20 units. In these larger sizes the engine and generator are brought to site separately and assembled along with ancillary equipment.

Only large capacity diesel, natural gas or biofuel reciprocating engine generators are considered in these guidelines as gasoline powered systems are generally not used in the energy sector. Diesel generators, sometimes as small as 250 kilovolt amps, are widely used at power plants not only for emergency power, but also many have a secondary function of feeding power to utility grids either during peak periods, or periods when there is a shortage of large power generators.

One or more diesel generators operating without a connection to an electrical grid are said to be operating in "island" mode. Several parallel generators provide the advantages of redundancy and better efficiency at partial loads. An island power plant intended for primary power source of an isolated community will often have at least three diesel generators, any two of which are rated to carry the required load. Groups of up to 20 are not uncommon.

Diesel engines are often used for back up generation, usually at low voltages. However most large power grids also use diesel generators, originally provided as emergency back up for a specific facility such as a hospital, to feed power into the grid during certain circumstances.

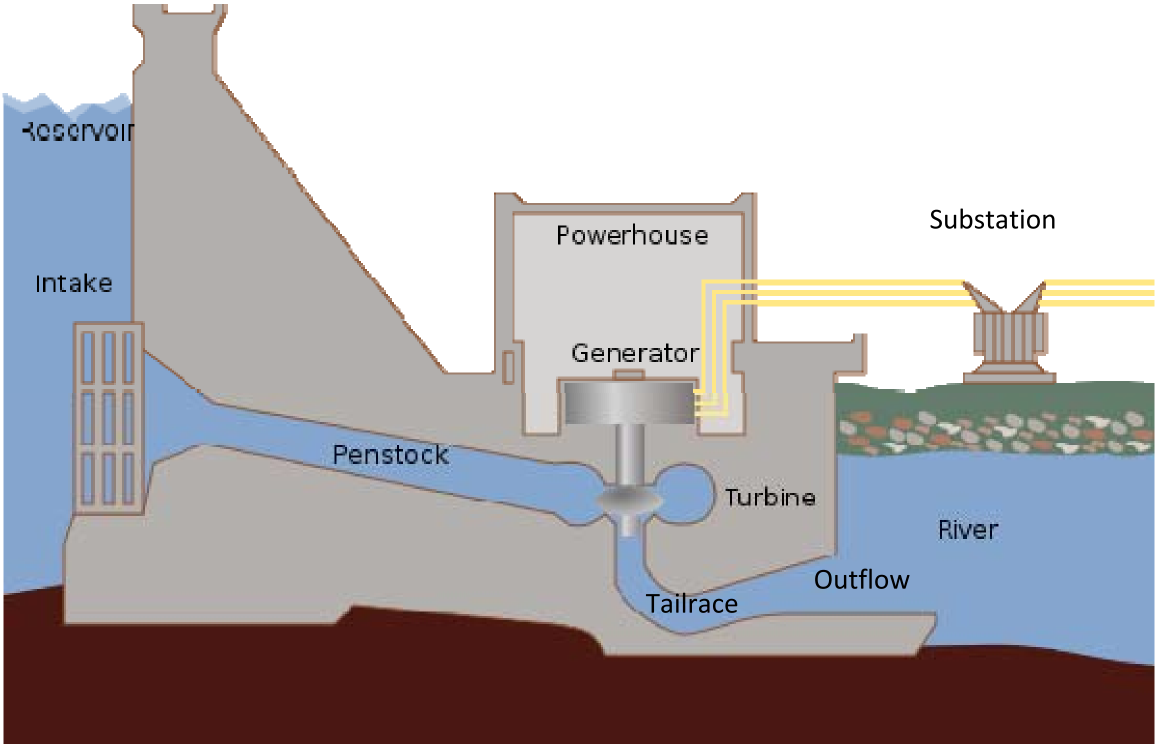
2.3. Hydropower

Hydropower refers to any project that produces electricity by using the gravitational force of falling or flowing water to generate electrical energy. Hydropower is subdivided into two categories: hydroelectric power and hydrokinetic power. Hydroelectric power generates electricity from the flow of water, generally using a dam or a diversion, whereas hydrokinetic projects generate electricity from the movement of waves or currents without the use of a dam or diversion. Micro-hydroelectric refers to hydroelectric power systems of 100 kW capacity or less and can include technologies that require neither a dam nor a diversion.

2.3.1 *Hydroelectric Power*

There are two types of hydroelectric power projects: conventional and pumped storage. Each is described in its own subsection below. Both types of projects have common components, as can be seen in Figure A-16:

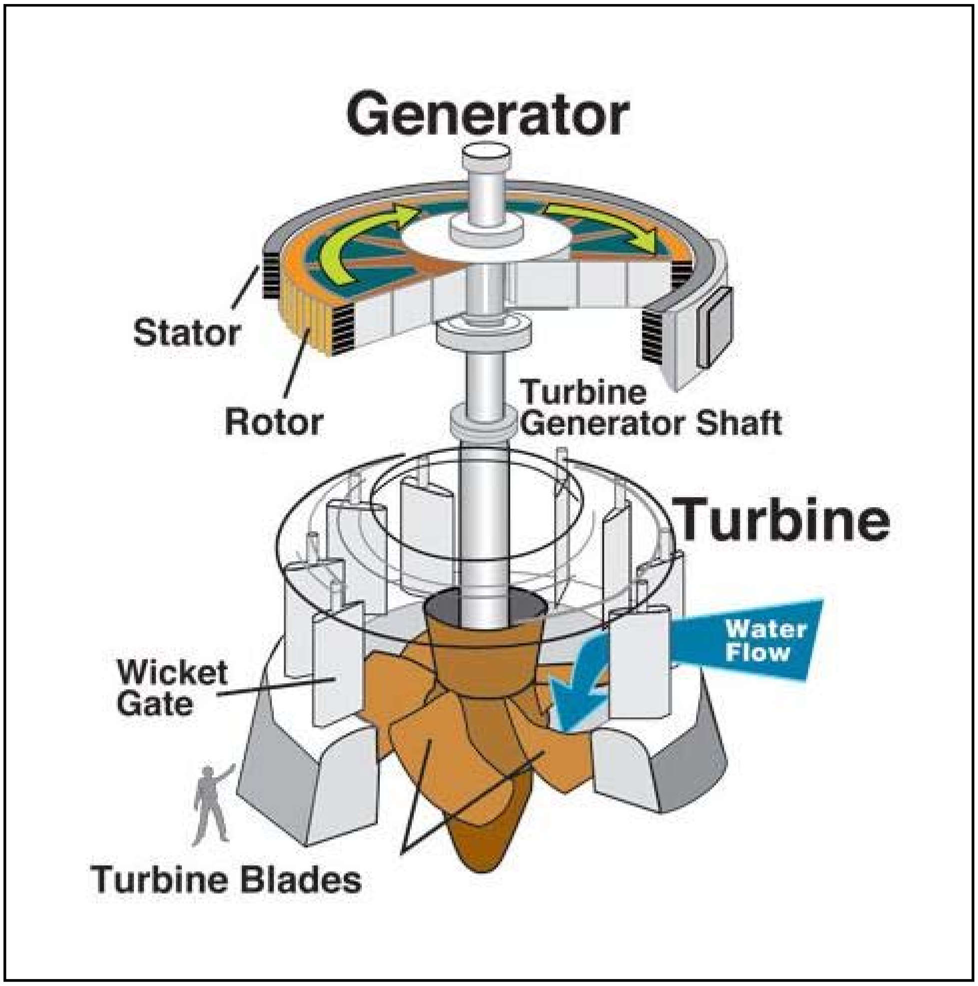
Figure A- 16: Hydroelectric dam diagram



Source: Based on a diagram from the Tennessee Valley Authority.
http://www.tva.gov/power/images/hydro.png

- Intake – gates on the dam or diversion through which water flows via gravity. Most intakes will have gates for controlling or stopping flow as well as screens to keep debris and fish out of the system.
- Penstock – a pipeline or tunnel that leads from the intake to the turbine. Water builds up pressure as it flows through penstock.
- Powerhouse – a structure housing the turbine and generator, and often components of the substation.
    - Turbine – a rotary shaft with large blades which turn when the water from the penstock flows across the blades (Figure A-17).
    - Generator – attached to and turned by the turbine. In a large plant, a turbine can weigh as much as 172 tons and turn at a rate of 90 revolutions per minute (rpm).
- Tailrace – a channel, pipeline or tunnel that carries the water from the turbine to the outflow.

Figure A- 17: Water turbine



Source: U.S. Corps of Army Engineers
http://www.nwp.usace.army.mil/HDC/edu_genexcit.asp

- Outflow – the point where water that has passed through the turbine is returned to the river.
- Substation – the facility that prepares the electricity produced by the generator(s) for transmission by the use of transformers to raising its voltage to transmission levels and switches and breakers to allow control of electrical flow.

Hydroelectric power is categorized by capacity and hydraulic head. Capacity is expressed in kilowatts kW or megawatts (MW). Plants with a capacity less than 5 kW are called pico. Between 5 and 100 kW they are micro. Mini plants have a capacity of 100kW to 1 MW. Small plants have a capacity of from 1 to 30MW, and large plants have a capacity greater than 30 MW. In the past, most hydroelectric projects connected to the grid in CAFTA-DR countries were large. But in the past several years, several mini and small hydroelectric projects have been constructed and put into operation.

Hydraulic head refers to the altitude change between the water surface at the intake to the penstock and the turbines. Low head is less than 30 meters. Medium head is 30 to 300 meters, and high head is greater than 300 meters. The energy created by the moving water depends on the volume flowing past the turbine and the head. As the volume and head increase, so does the electricity generated.

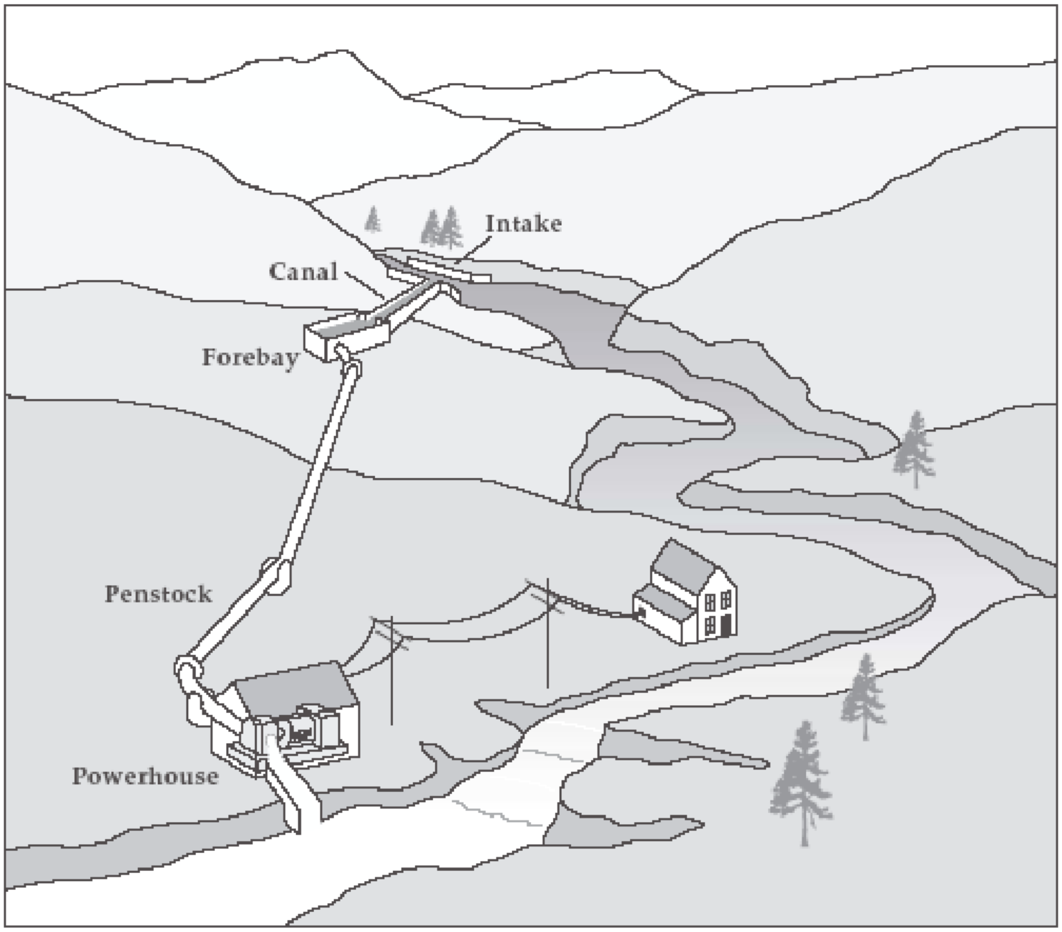
2.3.1.1. Conventional Hydroelectric

Conventional projects use a dam or diversion. They may operate in a run-of-the-river mode, where outflow from the project approximates inflow, or peaking, where flows are stored and released on a daily, monthly, or seasonal basis. Only projects with a dam and reservoir can operate in a peaking mode. A typical diagram of a dam project is shown in Figure A-16. The water in the reservoir is considered stored energy. When the gates open, the water flowing through the penstock becomes kinetic energy because it's in motion, and can be used to turn the turbines and generate electricity on demand. In dams, the head is determined by the amount of water in the reservoir, with the head being highest when the reservoir is full. To increase “head” for electrical generation, the developer may construct the powerhouse downstream from the dam, diverting water from a section of river known as the bypassed reach.

Project that use diversions may have small dams in the river to create the diversion, or may use other instream structures to divert the water. Figure A-18 shows a typical diversion hydroelectric project. Water is usually diverted into a canal that travels at a low gradient until it reaches a point where the water can be delivered into a high gradient penstock. At this point there is a head works or a forebay that directs the water into the penstock. The water flowing through the penstock creates the head necessary to turn the turbines.

The stretch of river between the intake and the outflow is called the bypass reach. Those projects that use dams for diversion have the potential to divert all of the water in the river, leaving the bypass reach dry some or all of the time.

Figure A- 18: Diversion hydroelectric project



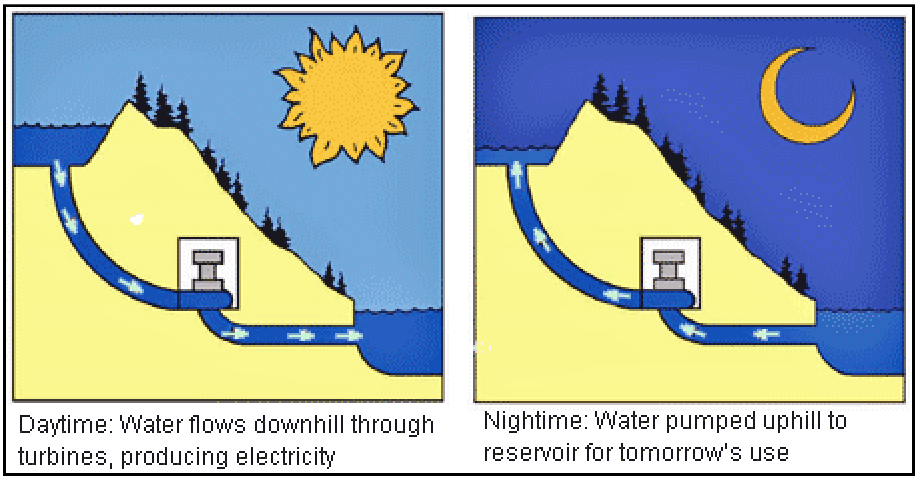
Source: World Bank. Renewable Energy Toolkit Technology Module. Pg. 3.
http://siteresources.worldbank.org/INTRENENERGYTK/Resources/REToolkit_Technologies.pdf

Most micro-hydroelectric projects are diversion and run-of-river projects. Some projects, however, may have small impoundments. Others may use instream turbines, requiring no dam or diversion. These systems, however, are for very small projects and generally are not used to provide power to the grid.

2.3.1.2. Pumped Storage Hydroelectric

In a conventional hydroelectric facility, water passes from the intake, through the turbine and out the outflow one time. In a pumped storage facility, water may pass through the turbine multiple times. This is accomplished by using two reservoirs, an upper reservoir and a lower reservoir. During periods of peak demand (during the day when offices and air conditioning are functioning) water flows via gravity from the upper reservoir, through the turbine to the lower reservoir. During this period, the upper reservoir level is allowed to drop. During off-peak periods (when people are sleeping), water in the lower reservoir is pumped back up to the upper reservoir through a reversible turbine. This process is shown in Figure A-19.

Figure A- 19: Pumped storage facility operation

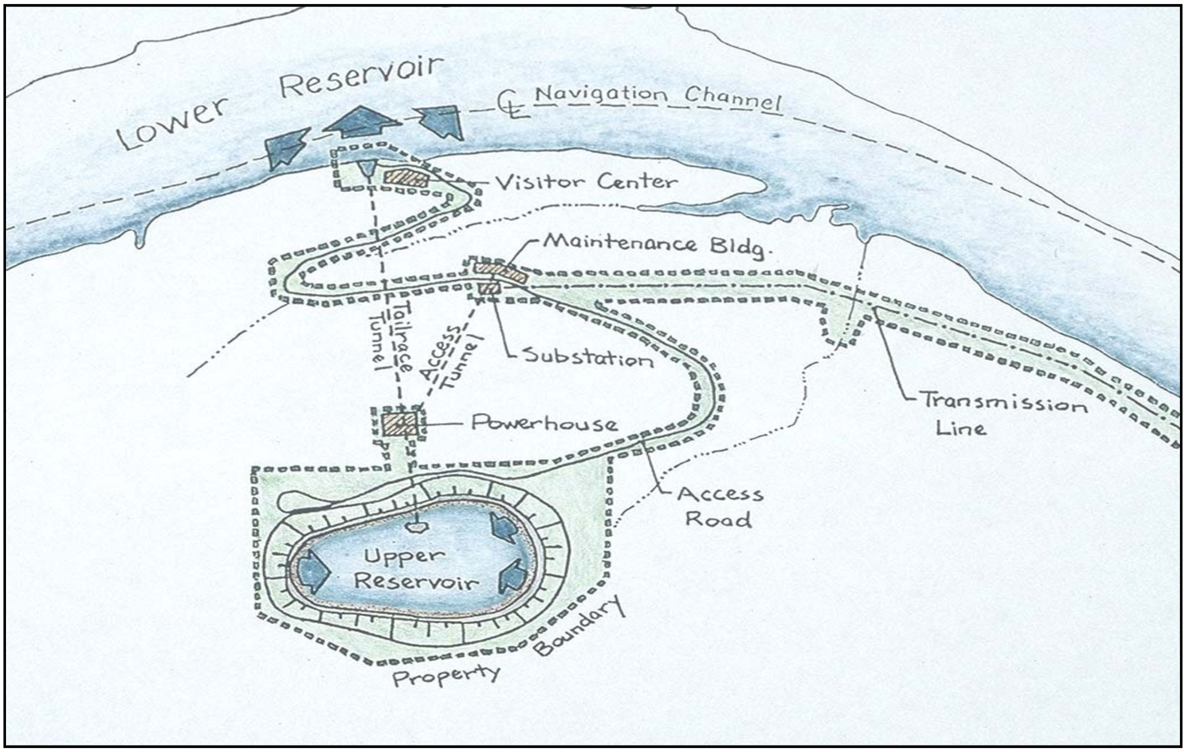

Daytime: Water flows downhill through turbines, producing electricity

Nighttime: Water pumped uphill to reservoir for tomorrow's use

Source: http://ga.water.usgs.gov/edu/hyhowworks.html

The energy used to pump the water is excess, off-peak energy. Essentially, the upper reservoir is being used as a battery that is recharged during off-peak periods by pumping water into it. The recharged upper reservoir will then have more water in it, ready to generate electricity during periods of peak consumption. Pumped storage reservoirs can be relatively small, or they can be located to take advantage of existing lakes or reservoirs (Figure A-20), so construction costs are generally lower compared with conventional hydropower facilities.

Figure A- 20: Pumped storage hydroelectric project layout



2.3.2 *Hydrokinetic Power*

Hydrokinetic power is defined as projects that generate electricity from waves or directly from the flow of water in ocean currents, tides or inland waterways without use of a dam. Hydrokinetic power is a newer development and it is estimated that 30% or more of global power needs in nations having enough coastal access could be generated using hydrokinetic power.

There are four types of wave energy devices: point absorbers, attenuators, overtopping terminators, and oscillating water column terminators (see Figure A-21). Current and tide energy devices consist of a rotor and generator, similar to wind turbines (Figure A-22). The two types are axial, which are typically horizontal and cross flow (either vertical or horizontal).

2.3.2.1. Point Absorbers

Point absorbers are floating structures with one component (generally a buoy) that moves up and down with wave action and another component that is fixed to the ocean floor or relatively fixed via a submerged damper. The two components move independently, causing a piston action, which is converted to energy via electromechanical or hydraulic converters. Point absorbers are not currently being used anywhere as a major energy source, but experimental versions have proven that they produce energy.

2.3.2.2. Attenuators

Attenuators are long, multi-segment floating structures oriented parallel to the direction of wave travel. The motion of the waves moves the segments independently, causing them to flex at the joints where the segments connect. The flexing action is converted into energy via hydraulic pumps or other converters. Those connected to hydraulic pumps pressurize hydraulic fluid, which is then used to drive a generator. The first commercial wave farm using Pelamis attenuators began operation in 2008 off the coast of Portugal (Aguçadoura). But since has shut down; first for technical reasons, then for later for financial reasons.

2.3.2.3. Overtopping Terminators

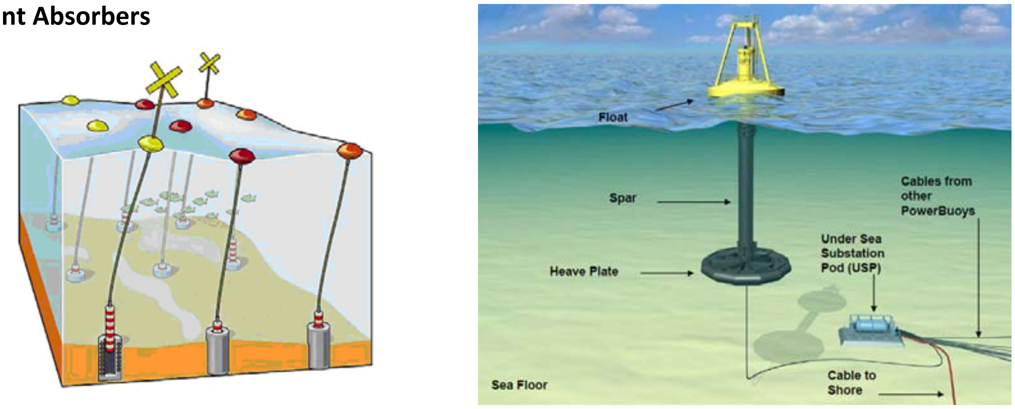
Overtopping terminators float at or near the ocean surface, perpendicular to the direction of wave travel and located near the shore where waves break. They have reservoirs that are filled when waves overtop the structure. After the device is overtopped, the water in the reservoir is above the average surrounding sea level. The water is then released through a controlled opening in the reservoir, and gravity causes it to fall back toward the ocean surface. The energy of the falling water is used to turn conventional, low-head hydro turbines. No overtopping terminators are currently proposed for use in the United States; however, projects and prototypes have been demonstrated in the United Kingdom, Denmark and Portugal.

2.3.2.4. Oscillating Water Column

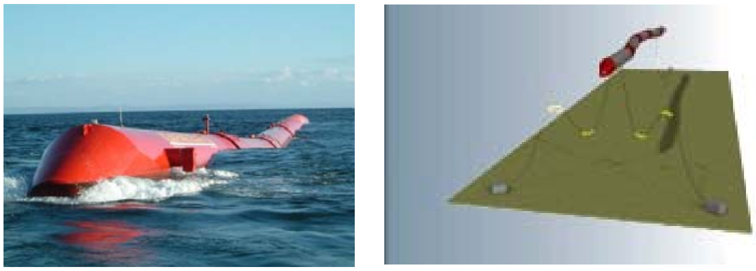
Oscillating water column (OWC) terminators are built on shore, perpendicular to the direction of wave travel. When waves break on shore, water enters through a subsurface opening into a chamber with air trapped above it. The wave action causes the captured water column to move up and down like a piston, forcing the air though an opening connected to a wind turbine. A full-scale, 500-kW, prototype OWC designed and built by Energetech is undergoing testing offshore at Port Kembla in Australia. The technology has also been demonstrated in the United Kingdom and Portugal, and at least two projects are under development in the United States.

Figure A- 21: Wave energy devices

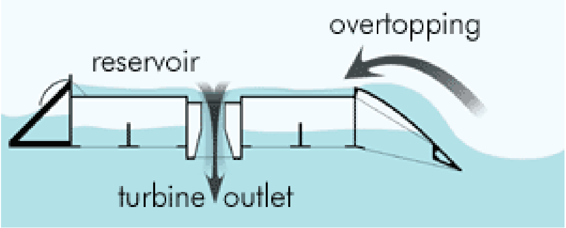
Point Absorbers



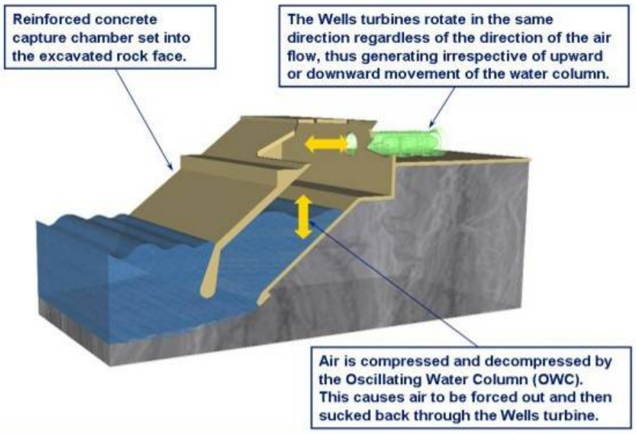
Attenuators



Overtopping Terminators



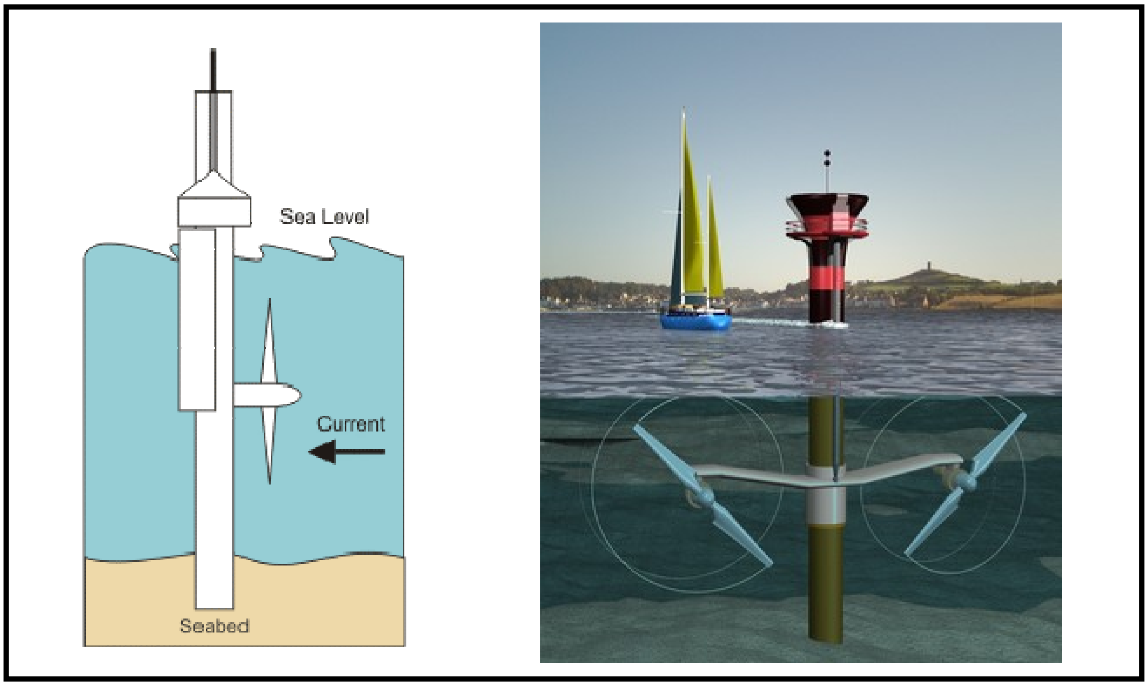
Oscillating Water Column Terminators


Reinforced concrete capture chamber set into the excavated rock face.

The Wells turbines rotate in the same direction regardless of the direction of the air flow, thus generating irrespective of upward or downward movement of the water column.

Air is compressed and decompressed by the Oscillating Water Column (OWC). This causes air to be forced out and then sucked back through the Wells turbine.

Figure A- 22: Tidal turbines



2.4. Solar Power

Solar energy can provide electrical power for distribution by utilities in sizes ranging from 10's of megawatts to a 1,000 megawatts. Solar power plants can be stand-alone or hybrid plants in which solar and other power sources are combined. Solar power can be used to generate electricity either directly through use of photovoltaic cells or by heating a fluid or gas which then drives a steam turbine or a Stirling or Brayton heat engine.

Solar power is divided into two generic types: concentrating solar power and photovoltaic (PV) (Figure A-23). The following subsections present basic information on each of these technologies.

Figure A- 23: Solar power technologies and their environmental requirements

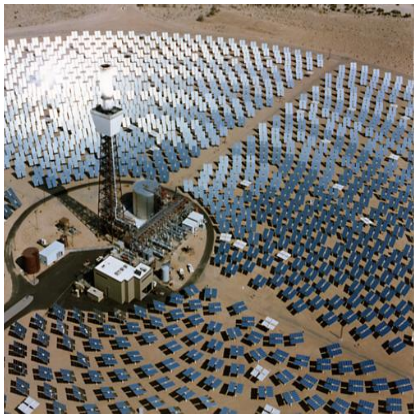
CONCENTRATING SOLAR POWER SYSTEMS

Parabolic Trough

- Rows of parabolic mirrors each with an absorber tube
- Thermal power plant
- Land requirement – 2 hectares/MW
- Water – 7,400 to 16,000 m^3/yr/MW

Linear Fresnel System

- Rows of long narrow mirrors low to ground focused on an absorber tube
- Thermal power plant
- Land requirement – 2 hectares /MW
- Water – 7,400 to 16,000 m^3/yr/MW



Power Tower

- Central tower (300-450 ft height)/field of mirrors
- Thermal power plant
- Land requirement – 3.6 hectares/MW
- Water – 7,400 to 16,000 m^3/yr/MW

Parabolic Dish

- Dish shaped mirror/heat piston engine
- Sterling or Brayton engine, no thermal plant
- Land requirement – 3.6 hectares/MW
- Water – 62 m^3/yr/MW

PHOTOVOLTAIC/CONCENTRATED PHOTOVOLTAIC

- Solar cell panels
- No thermal plant
- Land requirement – 4 hectares/MW
- Water – 62 m^3/yr/MW

2.4.1 *Concentrating Solar Power – Steam Turbines*

Concentrating Solar Power (CSP) technologies use mirrors to concentrate or focus the sun's light energy and convert it into heat to achieve sufficient fluid temperatures to efficiently produce electrical energy. Higher efficiencies reduce the plant's collector size and total land use per unit power generated, reducing the environmental impacts of a power plant as well as its expense.

There are two primary types of CSP plants that use the sun's heat to produce steam to turn steam turbines, those using parabolic troughs or linear Fresnel arrays and those using power towers and those using parabolic dishes. These systems are described in the following subsections. In both systems the super heated transfer fluid (usually some form of oil) is used to generate steam to power a turbine, similar to that used in other steam turbine power plants. As such, a solar thermal plant will have all of the components described in subsection 2.1 Steam Turbines.

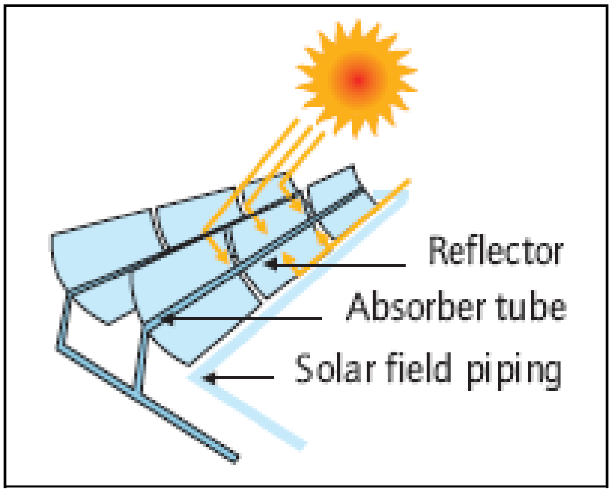
All parabolic trough, linear Fresnel and power tower plants generate heat to convert water to steam, but many plants also store excess heat for subsequent use. With current technology, storage of heat is much cheaper and more efficient than storage of electricity. The storage system is shown in the "Thermal Storage" component in Figure A-25. This design runs a heat transfer fluid through the parabolic array and to a heat exchanger for the water/steam system, turning the water into steam that then drives a steam turbine. When the sun is strong enough to provide more energy than is needed for the direct heat exchanger, a portion of the heated transfer fluid passes through an exchanger for the liquid salt system, which heats liquid salt from the cold tank and stores it in the hot tank. When the solar energy is insufficient to provide the necessary energy to transform water into steam, the hot liquid salt can be pumped through the heat exchanger, thus boosting the temperature of the transfer fluid. When the sun goes down, the storage system can continue to heat the fluid. In this way, the CSP plant can produce electricity day and night.

Because both types of systems produce steam for a steam turbine, they can also be hybridized with an external source of heat, such as a fossil fuel, biomass or biofuel boiler. In this way, when sunlight and heat storage is not sufficient, the plant can be operated with the boiler, thus improving the reliability of the system.

2.4.1.1. Parabolic Troughs and Linear Fresnel System

With a parabolic trough system the sun's energy is concentrated using parabolically curved, trough-shaped reflectors (Figure A-24) onto a receiver pipe running along the focal line of the curved surface in which there is a heat transfer fluid. A Fresnel system is similar to a trough system in that mirrors focus the sun's energy onto a pipe in which there is a heat transfer fluid. The mirrors, however, are in long narrow strips located close to the ground. Parabolic trough and linear Fresnel plants consist of a large array (two hectares per MW) of these reflectors tied into a steam turbine power system.

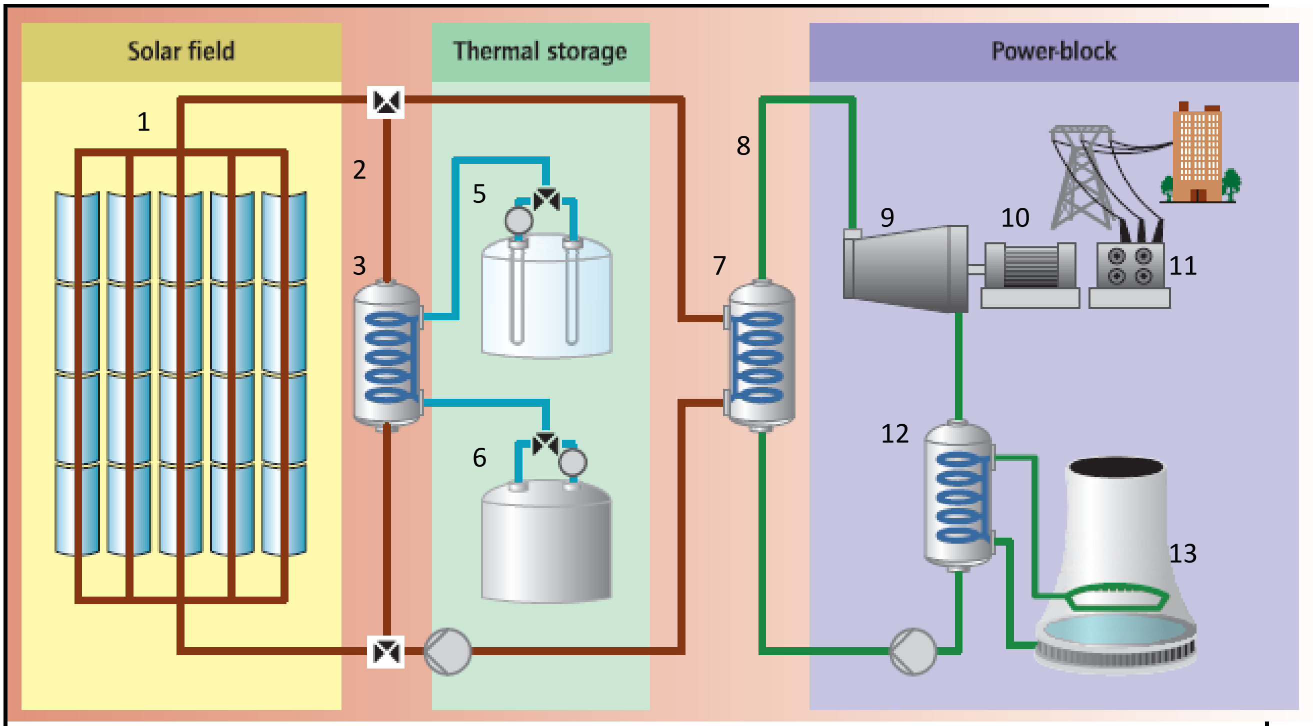
Figure A- 24: Solar parabolic trough diagram



Source: IEA 2010. Pg. 11.

Figure A-25 shows a diagram of parabolic trough solar plant. It shows how the parabolic trough arrays heat the transfer fluid, which in turn passes through a heat exchanger to generate steam for the "Power-block." The "Power-block" component of the diagram has the same components as any other steam turbine power plant. This diagram also includes a heat storage system as discussed above. A plant using linear Fresnel arrays instead of parabolic trough arrays would have the same diagram, with only the type of array being different.

Figure A- 25: Solar parabolic trough plant diagram with a liquid salt storage unit



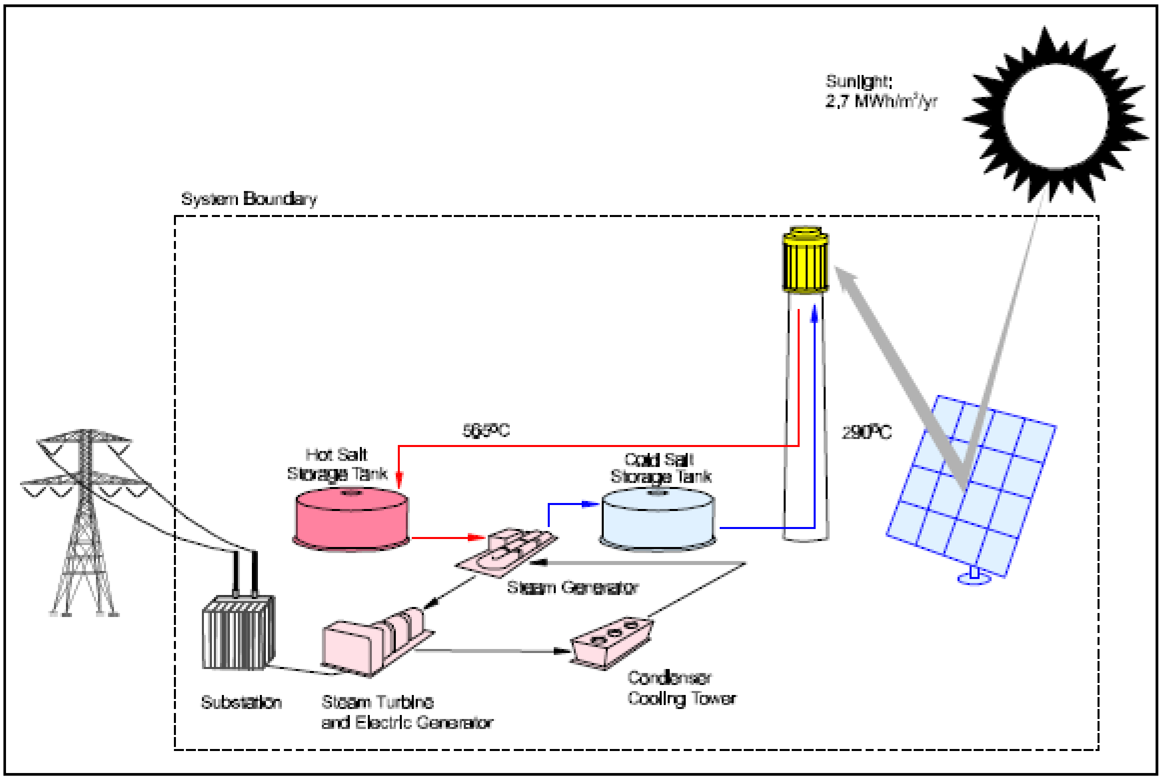
1. Parabolic troughs
2. Transfer fluid piping
3. Oil/salt heat exchange
4. Salt piping
5. Hot salt storage tank
6. Cold salt storage tank
7. Oil/Steam heat exchange
8. Water-Steam piping
9. Steam turbine
10. Generator
11. Substation
12. Heat exchange
13. Cooling Tower

Source: International Energy Agency. 2010. Technology Roadmap: Concentrating Solar Power. Paris. Pg. 13. http://www.iea.org/papers/2010/csp_roadmap.pdf

2.4.1.2. Power Towers

Power towers utilize an array of sun-tracking mirrors (heliostats) to focus sunlight on a receiver at the top of a tower in the center of the array, which contains a heat transfer fluid. Figure A-26 shows a typical diagram of a power tower generating facility. Although the diagram only shows one array, this is only an indication of how an array concentrates and reflects and sunlight onto the receiver. An actual power tower plant would have many arrays completely surrounding the tower, as shown in the photo in Figure A-23. The arrays require an area of 3.6 hectares per MW. Although the figure is not set up in the same format as Figure A-25, it has the same components and would operate in the same way as a parabolic trough system with heat storage capacity.

Figure A- 26: Solar power tower diagram



Source: http://www.solarpaces.org/CSP_Technology/docs/solar_tower.pdf

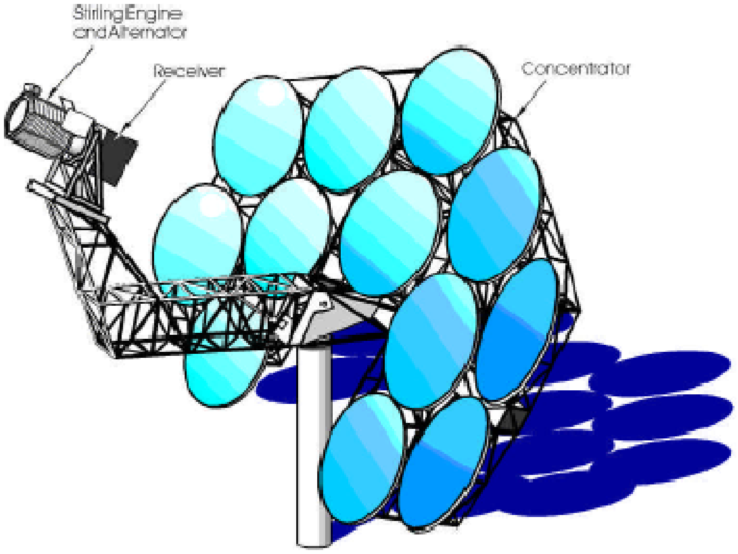
2.4.2 Concentrating Solar Power – Parabolic Dish-Engines

CSP parabolic dish systems use a mirror array (also called concentrators) to reflect and concentrate the sun’s energy on a receiver which transfers the energy to a working fluid or gas that in turn powers an engine that turns a generator or alternator (Figure A-27). These systems are often referred to as solar dish-engine systems. A solar dish power plant will have several of these dish- engines. The electrical energy is generated at each engine, so the fluid or gas does not need to be piped through the facility. The electrical energy is transported to the collector substation via electrical cabling. To make the arrays effective, each must track the sun in two axes, so that the reflected energy is always concentrated on the receiver.

The engines that are generally favored are the Stirling and Brayton engines. The Stirling engine is an internal combustion piston engine with an inert working fluid, usually either helium or hydrogen. It requires a cooling system, which is generally a radiator. The linear energy of the pistons is converted into rotary energy to drive a generator. The Brayton engine is a gas turbine. It discharges most of the waste heat in the exhaust. Both types of engines can be operated using other sources of external heat, such as fossil fuel, so that they can function even when solar radiation is too low or non-existent.

Solar-dish systems require about the same area as power tower systems, 3.6 hectares per MW. They use significantly less water than the other CSP systems because they do not have to condense steam coming out of turbines. Water use at these facilities is primarily for washing mirror surfaces.

Figure A- 27: Schematic of a dish-engine system with stretched-membrane mirrors



Source: http://www.solarpaces.org/CSP_Technology/docs/solar_dish.pdf

2.4.3 *Solar Photovoltaic*

A solar cell is a device that converts sunlight into electric current. The cell is constructed of semiconductor materials similar to those used in computer chips. When exposed to the sunlight, these materials absorb photons and release electrons. The free electrons can be captured and converted into electrical energy. There are fourteen competing types of photovoltaic cells, including monocrystalline silicon, polycrystalline silicon, and amorphous cells. It is too early to know which technology will become dominant.

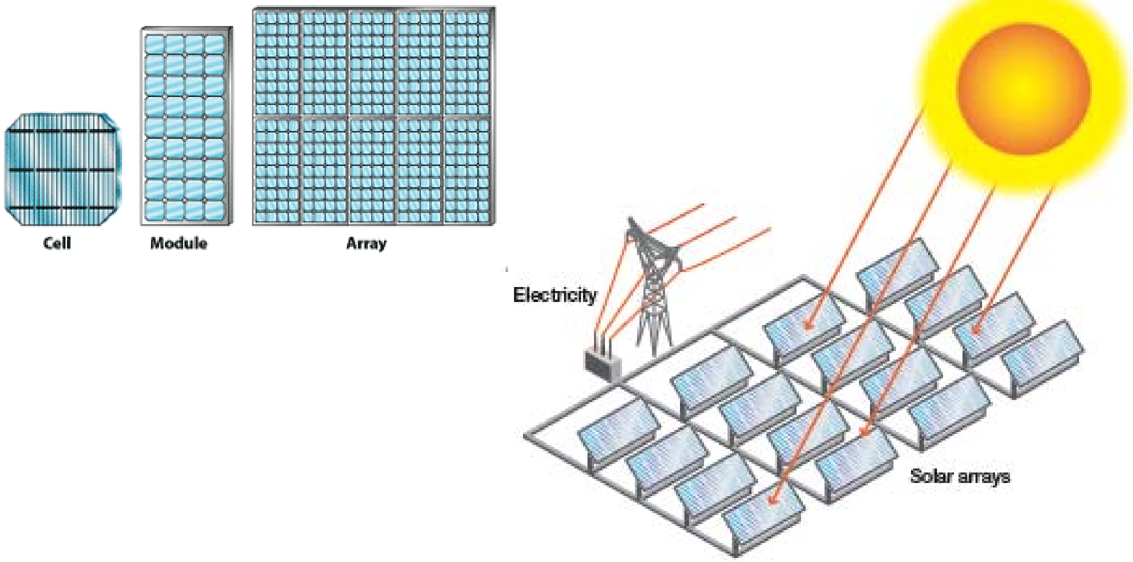
Each solar cell is generally very small and capable of generating only a few watts of electricity. They are typically combined into modules of about 40 cells, and the modules are assembled into photovoltaic (PV) arrays up to several meters on a side. A PV generating facility will have hundreds of these arrays connected together and set at a fixed angle facing south, or mounted on tracking devices that follow the movement of the sun (Figure A-28). A single-axis array tracks the sun from East to West during the day and can provide 30%–40% more energy than a fixed array.

The energy collected by the arrays is direct current, so it has to be transformed into alternating current before it can be delivered to the grid. The conversion is accomplished using inverters. The resulting energy is than adjusted to the necessary voltage and frequency with the use of transformers, switches and control circuits.

Concentrating PV (CPV) systems are a relatively new method of electricity generation from the sun. CPV systems employ lenses and mirrors to focus greater amount of solar energy onto highly efficient solar cells. This greatly increases the efficiency of the cells. CPV systems must track the sun to keep the light focused on the PV cells, which generally requires highly sophisticated tracking devices.

CPV systems require 4 hectares per MW, the largest land requirement of any of the solar power systems. As with solar-dish systems, the only water requirements at these facilities are for cleaning the arrays.

Figure A- 28: Schematic of a photovoltaic power generating system

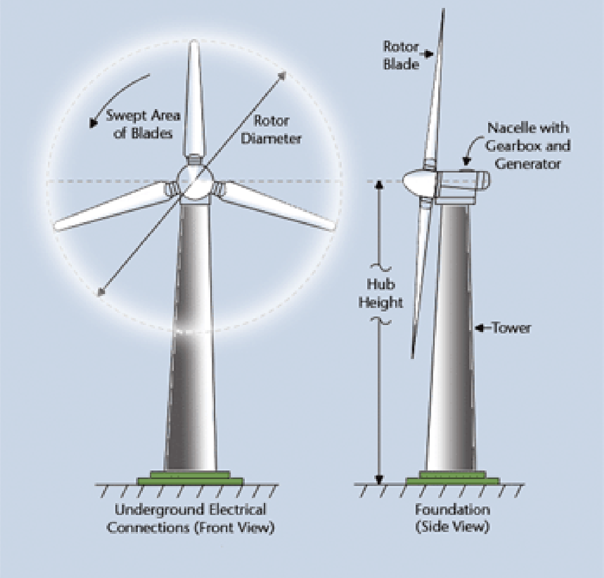


Sources: U.S. Department of Energy, http://solareis.anl.gov/documents/docs/NREL_PV_2.pdf and http://solareis.anl.gov/guide/solar/pv/index.cfm

2.5. Wind Power

Wind power converts the movement of air – wind into electrical energy much in the same way as hydropower converts moving water into electricity. Air flows past the blades of the wind turbine, converting the flowing motion into rotary energy. That energy is then used to spin a shaft that leads from the hub of the rotor to a generator. The generator turns that rotational energy into electricity.

Figure A- 29: Horizontal axis wind turbine



Source: http://ec.europa.eu/research/energy/nn/nn_rt/nn_rt_wind/images/wind_en_1370.gif

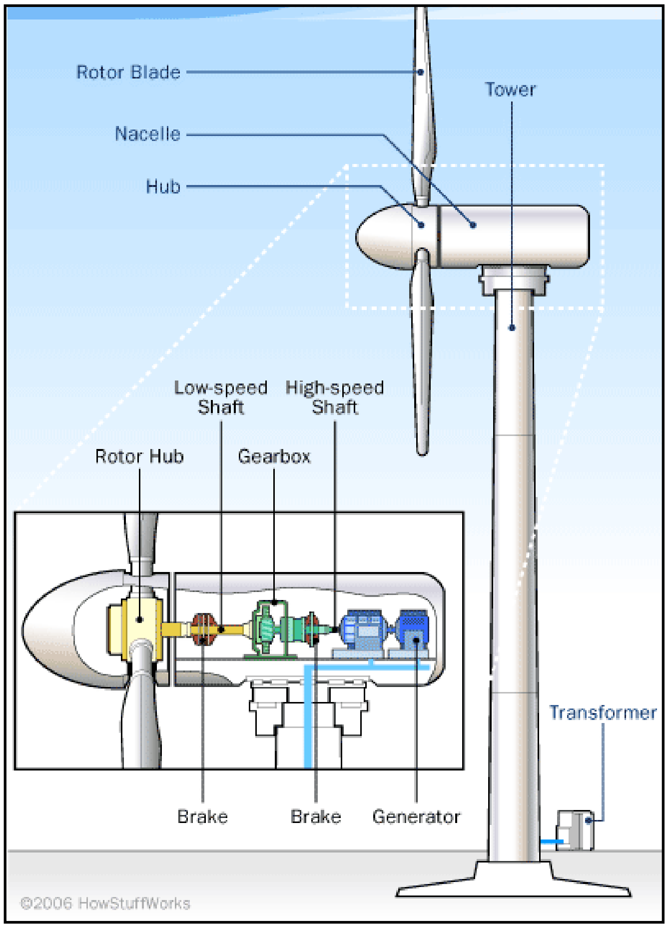
There are two general types of wind turbine, horizontal and vertical axis. Horizontal axis wind turbines (HAWT), the more commonly used type, are comprised of blades situated perpendicular to the direction of wind flow and are typically like a very large two- or three-bladed aircraft propeller (Figure A-29). All commercially produced, utility-scale wind turbines are HAWTs. HAWTs need to constantly align themselves with the wind (either into the wind or with the wind, depending upon the design of the turbine) using a yaw-adjustment mechanism. HAWTs use a tower to lift the turbine components to an optimum elevation for wind speed (and so the blades can clear the ground) and take up very little ground space since almost all of the components are up to 80 meters in the air. The towers require a substantial foundation. HAWTs are generally described referring to their hub height and rotor diameter (Figure A-29).

Current utility-grade wind turbines are 100 meters or higher at the hub, and typically have capacities of from 100 kilowatts to as large as five megawatts. Larger wind turbines are grouped together into wind farms.

Large HAWT have several components, as shown in Figure A-30:

- <u>Rotor Blades</u> that capture the wind's energy and sends it to the hub. Most commercial HAWT turbines have either two or three blades.
- <u>Rotor Hub</u>, where the energy from the blades is converted to rotational energy and passed on to the low speed shaft.

Figure A- 30: Horizontal axis wind turbine components

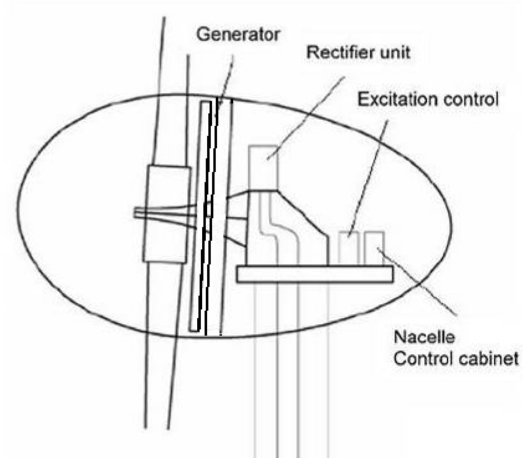


- Nacelle, the casing that holds:
    - Low Speed Shaft that transfers rotational energy into the gear box.
    - Gearbox that increases the speed from the low speed shaft from about 15 to 60 rpm to about 1000 to 1800 rpm, the rotational speed required by most generators to produce electricity.
    - High Speed Shaft that drives the generator.
    - Generator that generates electricity using electromagnetism.
    - Brakes that stop rotation of shaft in case of power overload or system failure.
- Yaw Drive and Motor (not shown in the figure) located at the top of the tower and below the nacelle to move rotor to align with direction of wind. They are controlled by a controller connected to a wind vane to sense the direction of the wind. In some designs, the yaw motor and controls are located inside the nacelle.
- Tower that supports the rotor and nacelle and lifts entire setup to higher elevation where blades can safely clear the ground. Towers are made from tubular steel (shown in figure), concrete or steel lattice.
- Power Line (inside the tower) that carries electricity from the generator down to the transformer.
- Transformer that increases voltage that comes from the generator (from 500 to 1,000 volts) up to distribution levels (thousands of volts), so that it can be sent via cables to the collection point where the power from all of the turbines are collected.

In addition to these components, most wind turbines have an anemometer to measure wind speed, which is connected to a controller inside the nacelle that starts up the machine at wind speeds of about 8 to 16 miles per hour (mph) and shuts off the machine at about 55 mph. Turbines do not operate at wind speeds above about 55 mph because they might be damaged by the high winds. The controller also monitors the performance of other components in the system and shuts down the turbine should something be malfunctioning.

There is another type of HAWT that is gaining some popularity for electrical power generation, the direct drive or gearless wind turbine. This design consists of two circular arrays of magnets surrounded by conductive wire set parallel to each other and to the rotor blades inside the nacelle (Figure A-31). One is attached to the shaft of the rotor. The other is held in a fixed position. The act of spinning the array attached to the generator over the fixed array generates electrical power using the principle of electromagnetism. These types of turbines have fewer moving parts and thus are easier to maintain and generate less vibration and noise. However, they produce direct current, so require the use of converters to produce electrical current necessary for commercial production. Direct drive turbines were initially small capacity units, but some major wind turbine companies are now investing into their development and are producing large, commercial direct drive turbines.

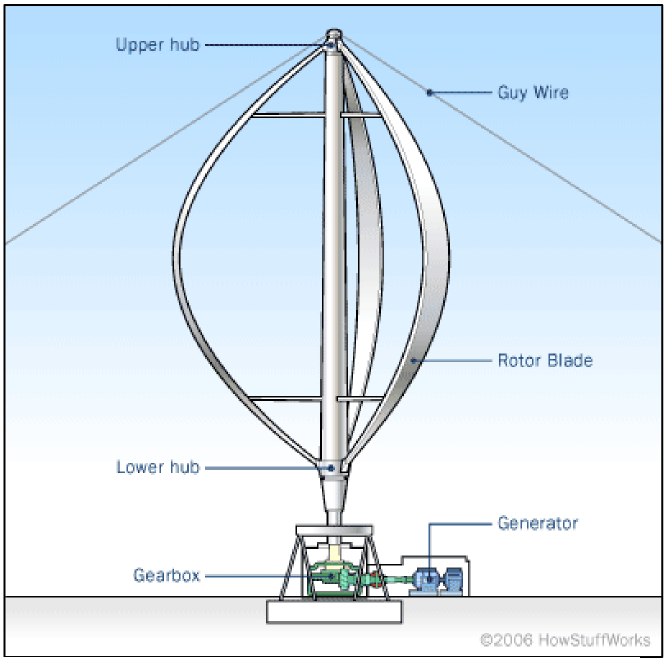
Figure A- 31: Direct drive wind turbine



Source: http://www.eolectric.com/assets/honeywood/images/techno_pic1_big.jpg

Vertical-axis wind turbines (VAWTs) are rare. The only one currently in commercial production is the Darrieus turbine, which looks kind of like an egg beater (Figure A-32). In a VAWT the shaft is mounted on a vertical axis perpendicular to the ground. Because of their design, VAWTs are always aligned with the wind, so there is no mechanism required to adjust to wind direction, it cannot start on its own and needs a boost from its electrical system to get started. Instead of a tower, it typically uses guy wires for support, so the rotor elevation is lower. Lower elevation means slower wind due to ground interference which reduces wind speed, so VAWTs are generally less efficient than HAWTs. All equipment is at ground level which improves accessibility for maintenance and repairs, but it also means that each turbine has a larger footprint than a HAWT. VAWT systems are, however, gaining in popularity due to easier installation and service, lower visual and sound profile, lower impact on bat and bird populations, and ability to collocate on the footprints of existing HAWT farms thereby generating additional power at a lower incremental cost per additional MW installed.

Figure A- 32: Horizontal axis wind turbine



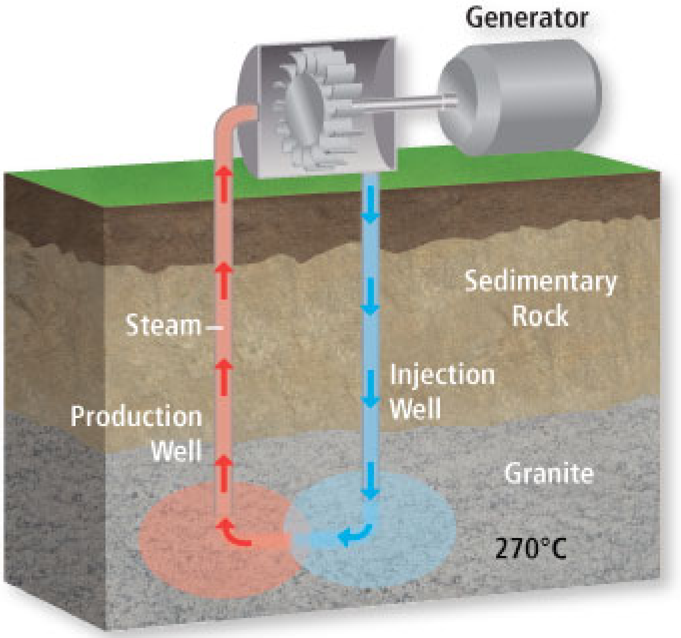
Source: http://science.howstuffworks.com/environmental/green-science/wind-power2.htm

Due to changing meteorological conditions and wind speed variability, wind is an inconsistent source of energy, thus wind energy requires storage or backup generation systems. This could include demand-side energy management, but if that is insufficient the project will have to include backup power generation from hydropower, fossil fuel or other sources.

2.6. Geothermal Power

Geothermal power plants are steam turbine systems with geothermal heat providing the heat for producing steam. As such, they have all of the components described in subsection 2.1 Steam Turbines. There are three types of geothermal power plants: dry steam, flash steam, and binary cycle. Dry steam power plants pipe steam directly from underground wells to the power plant, where it is directed into a steam turbine/generator unit (Figure A-33). These systems require sources of underground steam, which are not common.

Figure A- 33: Dry steam geothermal power plant



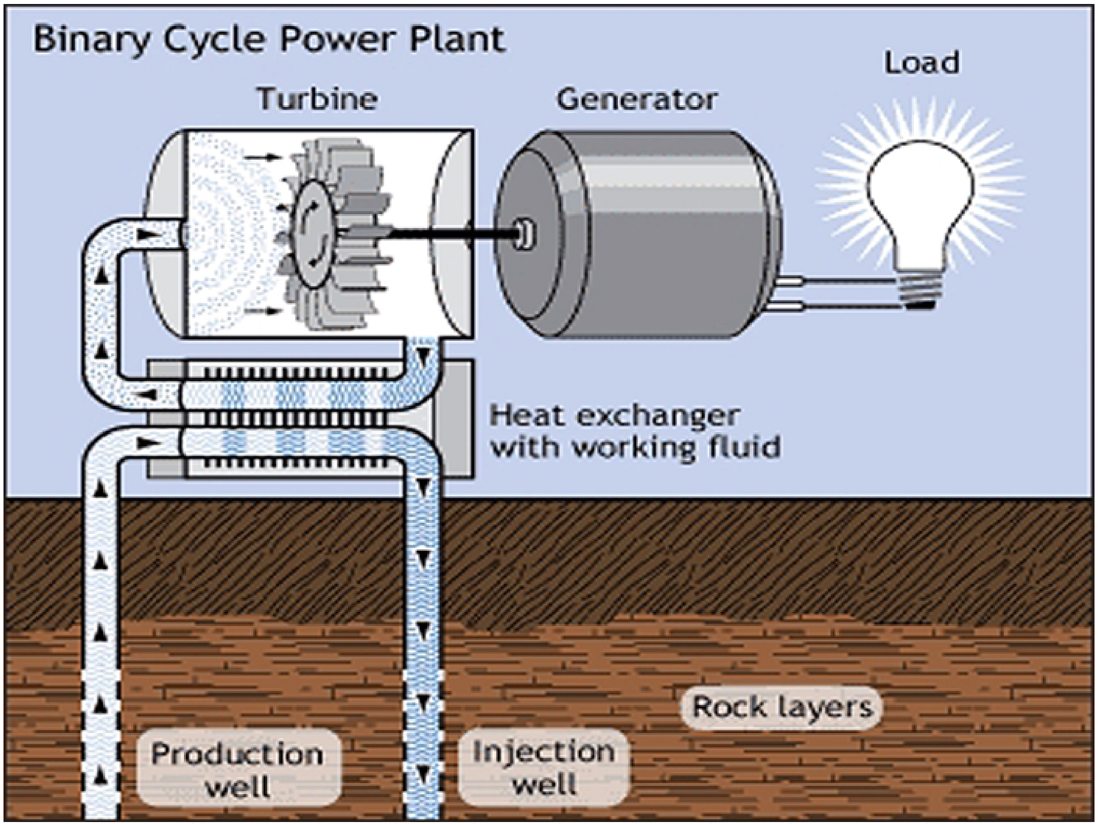
Source: http://content3.jason.org/common/uploads/gateduploads/oip_curriculum/images/oip_m4_mb8_1.jpg

Flash steam power plants are the most common. They use geothermal reservoirs of water with temperatures greater than 182°C, which flows up through wells under its own pressure. As it flows upward, the pressure decreases and some of the hot water boils into steam. The steam is then separated from the water and used to power a steam turbine/generator.

Both dry and flash steam plants are open-cycle systems, meaning that the geothermal water and steam is not fully contained and can off-gas air emissions.

Binary cycle power plants operate on water at lower temperatures from about 107° to 182°C. These plants use the heat from the hot water to boil a working fluid, usually an organic compound with a low boiling point. The working fluid is vaporized in a heat exchanger and used to turn a turbine/generator unit or a Sterling engine/generator. The water is then injected back into the ground to be reheated (Figure A-34). The water and the working fluid are kept separated during the whole process, so there are little or no air emissions. For that reason, these plants are called closed-cycle systems.

Figure A- 34: Binary cycle geothermal power plant (closed-cycle)



Source: http://www.eriding.net/media/photos/environment/power/geothermal/090407_rfoster_mp_env_power_geothermal_binaryplant.jpg

2.7. Transmission Substation

Up to this point electricity has been produced but it must pass through one more stage before it is ready to be transmitted somewhere for use. Electric power that leaves generators or photovoltaic cells needs to be prepared for transmission. This is done at a transmission substation. This substation brings together energy generated by different points in the plant (different generators or photovoltaic cell arrays) and uses large transformers to increase voltage to 155,000 to 765,000 volts (depending on the transmission line design and the distance that the electricity has to travel) in order to reduce line losses during transmission. The transmission substation also has switches and circuits to control the electricity and allow power to specific lines to be turned on and off as needed for maintenance and repair. If the electricity generated is direct current, as from photovoltaic cells and direct drive wind, the substation also has converters or inverters to convert the current to alternating current.

Geothermal electric plants have until recently been built exclusively on the edges of tectonic plates where high temperature geothermal resources are available near the surface. The development of binary cycle power plants and improvements in drilling and extraction technology may enable enhanced geothermal systems over a much greater geographical range.

3 ELECTRIC POWER TRANSMISION

Electric power transmission is the bulk transfer of electrical energy between the point of generation and multiple substations near a populated area or load center. Electric power transmission allows distant energy sources to be connected to consumers in population centers. Transmission may be via overhead or underground lines, however, most transmission is done with overhead lines because they are less costly to construct and easier to maintain. Underground lines are generally restricted to urban areas.

A power transmission network is referred to as a “grid.” Multiple redundant lines between points on the grid are provided so that there are a variety of routes from any power plant to any load center. The specific routing of electricity on the grid at any time is based on the economics of the transmission path and the cost of power.

Power plants produce three phase alternating current (AC) electricity, which is boosted to high voltage by transformers for transmission. For this reason, out of every power plant come three lines and transmission is done with three lines, one each for the three phases of power being produced. Each group of three lines is called a circuit. High voltage direct current is sometimes transmitted for long distance transmission or some undersea cables, or for connecting two different AC networks. Electricity is usually transmitted at high voltages (110 KV or above) to reduce the energy lost in transmission.

3.1. Right-of-Ways

Every transmission line has right-of-ways, the areas of land over which, or under which, the transmission line runs. The owner of the transmission line does not own these lands, but has agreements with the landowners that can restrict uses of the land and access to transmission structures. Overhead lines generally have right-of-ways with widths of 25 or more meters. The width depends upon the width of the towers. Sometimes one right-of-way may carry more than one set of towers, in which case the right-of-way must be wider. In some cases, new circuits can be added to existing towers, so that the right-of-way can remain the same. Underground lines need a narrower surrounding strip of about 1 to 10 meters.

Right-of-ways have to be managed to ensure that transmission structures are not compromised. In addition, right-of-ways for overhead lines must be maintained to ensure that vegetation and activities do not infringe upon the lines.

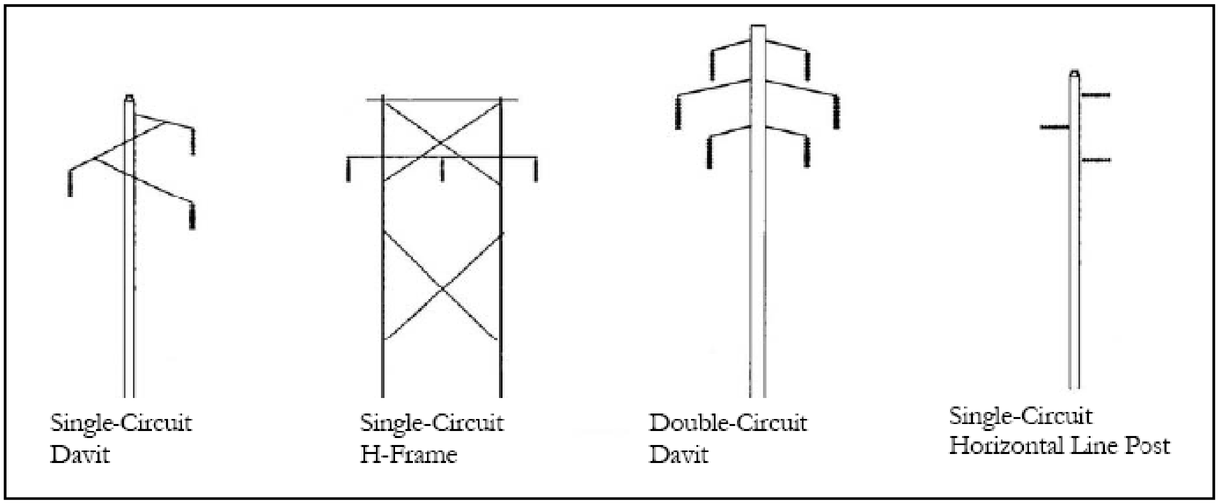
3.2. Overhead Transmission Lines

Overhead transmission lines are made of bare metal, uninsulated conductors. The conductor material is nearly always an aluminum alloy, made into several strands and possibly reinforced with steel strands. The conductors are usually 2 to 3 centimeters in diameter. Improved conductor material and shapes are regularly used to allow increased capacity and modernize transmission circuits. Because the lines are uninsulated, minimum clearances must be observed to maintain safety both in terms of access from the ground and from the airspace.

Power is conducted in circuits, with each circuit being made up of three lines, one each for each phase of electricity being transmitted. In addition to these three lines, there is usually a fourth, smaller diameter line that runs above the power conductors called a shield line. The shield line carries no electricity, and is designed to protect the conductors from lightening strikes. Sometimes towers may carry two circuits (six power lines) in which case the system is called a double-circuit.

The lines are suspended on towers. Transmission towers can range from 20 to 45 meters in height. The lines either hang from or are run over towers on insulators to which keep the electrical energy from coming in contact with the towers. Transmission towers can be constructed of wood or metal and can have various shapes. Some typical tower configurations are shown in Figure A-35.

Figure A- 35: Different transmission tower configurations



Source: Public Service Commission of Wisconsin, no date, Figure 4.

The spacing of towers depends upon their height, their load capacity limits and the minimum ground clearance required at the low point in the lines. Single-pole structures may require concrete foundations in areas with weak or wet soil. Guy wires or other support structures may be required if the transmission route must make a change in direction.

3.3. Underground Transmission Lines

Although more costly and therefore less used, burying power cables underground can assist the transmission of power across:

- Densely populated urban areas
- Areas where land is unavailable or planning consent is difficult
- Rivers and other natural obstacles
- Land with outstanding natural or environmental heritage
- Areas of significant or prestigious infrastructural development
- Areas with high risk of damage from severe weather conditions (mainly wind)
- Areas with concerns about emission of electromagnetic fields (EMF). (All electric currents generate EMF, but the shielding provided by the earth surrounding underground cables restricts their range and power.)

Most high-voltage underground cables for power transmission that are currently sold on the market are insulated by a sheath of cross-linked polyethylene (XLPE). Some cable may have a lead or aluminum jacket in conjunction with XLPE insulation to allow for fiber optics to be seamlessly integrated within the cable.

Instead of towers, underground cables have periodic manholes that allow access to the cables, or at least some parts of the cables. In addition to higher installation costs, underground lines also have higher maintenance and operation costs. Whereas finding and repairing overhead wire breaks can be accomplished in hours, underground repairs can take days or weeks, and for this reason redundant lines are run. Operations are more difficult since the high reactive power of underground cables produces large charging currents and so makes voltage control more difficult.

3.4. Distribution Substation

At the other end of the system, before the power is distributed to consumers, the electrical power must be stepped-down from the high voltages at which it left the power plant. The place where the voltage is stepped down is called a distribution substation. A distribution substation typically does several things:

- It reduces voltage using transformers that step transmission voltages (in the tens or hundreds of thousands of volts range) down to distribution voltages (typically less than 10,000 volts).
- It stabilizes voltage going into distribution lines via voltage regulators, to prevent under- and over-voltage conditions.
- It has a “bus” that can split the distribution power off in multiple directions.
- It often has circuit breakers and switches so that the substation can be disconnected from the transmission grid or separate distribution lines can be disconnected from the substation when necessary.

APPENDIX B. ENERGY IN CAFTA-DR COUNTRIES

1 REGIONAL OVERVIEW

Initially all power generation utilities and transmission companies in the CAFTA-DR area were state-owned. Over the past several decades, however, independent power producers and private sector investors began participating in power generation and transmission, so that now only in Costa Rica does power generation and transmission remain a state-owned concern. Although many multinationals remain in Latin America with stakes in a few companies, there are now clearly six companies with a major presence. These are AES from the United States; AEI, a Cayman Islands based fund holding the former assets of Enron; the three Spanish companies: Endesa, Iberdrola, and Union Fenosa; and Suez (Hall 2007).

1.1. Fuel and Energy Use Data for CAFTA-DR

Table B-1 presents electricity generation indicators for the CAFTA-DR countries. Table B-2 presents data on production and consumption of electrical energy in each CAFTA-DR country. Production is disaggregated by type of generation. Consumption is disaggregated by sector.

As can be seen in Table B-1, there is a clear relationship between energy consumption per capita and GDP per capita in the CAFTA-DR countries. The countries with the highest per capita gross domestic product (GDP) (Costa Rica, Dominican Republic and El Salvador, respectively) also have the highest energy consumption per capita (Costa Rica, Dominican Republic and El Salvador, respectively). Costa Rica, the country with the highest per capita GDP, has a level of energy consumption per capita 4.6 times greater than that of Nicaragua, the country with the lowest per capita GDP. Per capita GDP is also strongly positively correlated with access. Ninety-nine percent of the population in Costa Rica has access to electricity, whereas only 70 percent have access in Honduras and 72 percent in Nicaragua. All countries, however, have made improvements in access over the past 10 years.

The relationship of per capita energy consumption to per capita CO_2 emissions, however, is not strong. This is because the source of the energy is as important of a factor as is the amount of energy consumed. Costa Rica has lower per capita CO_2 emissions than Dominican Republic, even though it consumes 1.34 times as much energy per capita, because 90 percent of its electrical energy is generated by hydroelectric and geothermal power, whereby 89 percent of electrical power in Dominican Republic is generated from the combustion of fossil fuels (Table B-2).

Table B- 1: Electricity generation indicators

Indicator	Costa Rica	Dominican Republic	El Salvador	Guatemala	Honduras	Nicaragua
Population (million)	4.53	9.84	6.13	13.68	7.24	5.68
GDP (billion 2000 USD)	23.52	36.07	16.42	26.09	10.50	5.13
Per Capita GDP (2000 USD)	5,192	3,666	2,679	1,907	1,450	903
Access to Electricity (% of Pop)	99.1	95.9	86.4	80.5	70.3	72.1
Electricity Consumption (GWh)	8,408	13,113	5,710	7,175	5,168	2,282
Per Capita Electricity Consumption (kWh/person)	1,863	1,393	953	543	715	402
CO2 Emissions (Mt of CO2)*	6.58	19.56	5.82	10.61	7.80	4.14
Per Capita CO_2 Emissions (t CO_2/person)	1.45	1.99	0.95	0.78	1.08	0.73

Notes:
* CO_2 Emissions from fuel combustion only. Emissions are calculated using the International Energy Agency's energy balances and the Revised 1996 IPCC Guidelines.
Sources: International Energy Agency: http://www.iea.org/country/index_nmc.asp for all but access
http://www.worldenergyoutlook.org/database_electricity/electricity_access_database.htm for access

The other three countries all derive 62 percent or more of their electrical power from the combustion of fossil fuels. Oil is the most commonly used fossil fuel in the region for electrical energy generation. Guatemala and Dominican Republic also have coal-fired power plants. Dominican Republic is the only country in the region that generates electric power using natural gas.

All of the CAFTA-DR countries are importers of fossil fuels. None of the countries have proven reserves of coal or natural gas, and although Guatemala has small proven reserves of oil, in 2008, it still only pumped 23 percent of the amount of oil it consumed (for all uses).

Until 2009, Costa Rica was the only country in the region that used wind power to produce commercial electric power, however, in 2009 a new wind facility began operation in Nicaragua. The potential exists to expand the use of wind in the region. The central mountainous ridgeline running from Costa Rica through Nicaragua and Honduras/El Salvador border and in to southeastern Guatemala has potential for wind development. Coastal wind energy is also attractive on the Atlantic coast, and to a lesser extent on the Pacific coast of Central America. Wind energy potential has been extensively studied in Dominican Republic by the National Renewable Energy Laboratory (Elliot 2001), which concluded that approximately three percent of the land area of Dominican Republic (coastal and high elevation) has good to excellent wind energy potential that could produce over 24 gigawatt hours (GWh) of electricity, or 50 percent more than the total amount of production in 2008.

The primary consumers of electrical power in all of the CAFTA-DR countries are residences, industry and commercial and public services. The distribution among these groups, however, varies among the countries. In Dominican Republic, El Salvador and Guatemala approximately 40 percent of all consumption is by industry, whereas in the other countries industry accounts for 23 to 28 percent of consumption. The largest residential consumption is in Costa Rica and Honduras, accounting for approximately 40 percent of consumption in each country, while the other residential consumption ranges from 32 to 34 percent in the other countries. Dominican Republic has the lowest consumption by commercial and public services (15%), with the other countries ranging from 27 to 35 percent. Only three countries have consumption by agriculture and forestry, and in all three cases these are the smallest category of consumers (Costa Rica 4%, Dominican Republic 11%, and Nicaragua 3%).

Table B- 2: Electrical power production and consumption in the CAFTA-DR countries in 2008

	Electricity (Gigawatt hours – GWh)					
	Costa Rica	**Dominican Republic**	**El Salvador**	**Guatemala**	**Honduras**	**Nicaragua**
Production from:						
Coal	0	2,133	0	1,131	0	0
Oil	677	9,528	2,298	2,322	4,049	2,167
Gas	0	1,996	0	0	0	0
Biomass	82	29	105	1,552	197	338
Waste	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0
Hydro	7,387	1,728	2,038	3,712	2,291	534
Geothermal	1,131	0	1,519	0	0	322
Solar PV	0	0	0	0	0	0
Solar Thermal	0	0	0	0	0	0
Wind	198	0	0	0	0	0
Tide	0	0	0	0	0	0
Other Sources	0	0	0	0	0	0
Total Production	**9,475**	**15,414**	**5,960**	**8,717**	**6,537**	**3,361**
Imports	96	0	83	5	0	28
Exports	-166	0	-89	-76	-12	0
Domestic Supply	**9,405**	**15,414**	**5,954**	**8,646**	**6,525**	**3,389**
Losses*	997	2,301	244	1,471	1,357	1,107
Final Consumption	**8,408**	**13,113**	**5,710**	**7,175**	**5,168**	**2,282**
Industry %	23	41	39	39	27	28
Transport %	0	0	0	0	0	0
Residential %	40	33	32	34	41	32
Commercial and Public Services %	33	15	30	27	32	35
Agriculture / Forestry %	4	11	0	0	0	3
Fishing %	0	0	0	0	0	0
Other Non-Specified %	0	0	0	0	0	0

Notes:
*Transmission losses as well as losses/use at the generating plants.
Source: International Energy Agency http://www.iea.org/country/index_nmc.asp

1.2. Power Transmission

Currently few electrical transmission interconnections exist in Central America, and those that do are often old and unreliable. In 2008, distribution losses in Central America ranged from 2 percent in El Salvador to 23 percent in Nicaragua with an average of 13 percent. Dominican Republic had a distribution loss in the same year of 13 percent. For all of the countries improvements in transmission and distribution systems over the past 10 years has resulted decreases in distribution losses.

The proposed Sistema de Interconexión Eléctrica para América Central (SIEPAC) or Central American Electrical Interconnection System is a project for a unified electricity transmission grid joining together all the Central American countries, which when it becomes operational will further reduce distribution losses and improve the efficiency of electrical energy use in Central America. The project entails the construction of nearly 1,800 kilometers (km) of transmission lines connecting 37 million consumers in

Panama (150 km), Costa Rica (490 km), Honduras (270 km), Nicaragua (310 km), El Salvador (290 km), and Guatemala (280 km). In 2003, SIEPAC was estimated to cost about US$320 million and was scheduled for completion in 2006. More than 90 percent of the rights of way for the line had been acquired by May 2007. Construction on the first towers did not begin until 2007. The project is now estimated to be completed by the end of 2011 at a cost of nearly $500 million.

The funding for the project is primarily coming from the Inter-American Development Bank in US$240 million of hard and soft loans to the six Central American countries and the Central American Bank for Economic Integration with an US$ 80 million in loans. Also participating in the financing is the Spanish government, six Central American nations, the Spanish multinational power company Endesa, and the Colombian firm ISA.

SIEPAC would be owned by Entidad Proprietaria de la Red, a regional operations entity created in 1999 with registration in Panama, and comprising the public utilities and transmission companies of the six participating countries (75 percent) and private capital (25 percent). In some countries integrated utilities are shareholders - ENEE of Honduras, ICE and CNFL of Costa Rica - while in others shares are held by transmission companies - INDE of Guatemala, ETESA of Panama, and ENTE of Nicaragua. In the case of El Salvador the utility CEL and the transmission company ETESAL own the shares jointly. The private shareholders are Endesa of Spain and ISA from Colombia. The project is currently managed by a unit under the Consejo de Electrificación de América Central.

2 CAFTA-DR COUNTRY OVERVIEWS

2.1. Costa Rica

Costa Rica relies upon hydroelectric power more than any other country in the CAFTA-DR region, with hydroelectric power providing 68 percent of the total power generation in the country (Figure B-1). Geothermal power is the second largest source of electrical power, providing 12 percent. The remaining 20 percent is supplied by oil (7%), wind (2%) and biomass (1%). Costa Rica is the only country in the CAFTA-DR region that uses wind power to generate electrical power.

As can be seen in Table B-3, hydroelectric power and geothermal have been the primary sources of electric power generation since at least 1999.

Figure B- 1: Costa Rica energy generation by fuel type 2008

Source of data: Table B-2

The state-run electrical utility Instituto Costarricense de Electricidad controls some 80 percent of installed electricity generating capacity. Twenty-seven privately-owned companies own about 13 percent of total installed capacity, with the remaining seven percent run by cooperatives for rural electrification. Four cooperatives (Coopelesca, Coope Alfaro Ruiz, Coope Guanacaste and Coope Santos) operate in rural regions of Costa Rica, all of them organized on a not-for-profit basis.

Table B- 3: Costa Rica energy trends 1998-2008

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Petroleum Products (1,000 Barrels/Day)										
Total Consumption	35.75	36.28	37.59	39.66	41.92	41.56	40.61	42.00	44.00	48.00
Fuel Oil Consumption	19.58	16.53	17.66	16.84	19.28	18.67	18.38	23.06	25.36	NA
Proved Reserves (Billion Barrels)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas (Billion Cubic Feet)										
Consumption	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proved Reserves (Billion Barrels)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal (Million Short Tons)										
Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Consumption	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	1.3
Electricity Net Generation (GWh)	6,073	6,782	6,813	7,343	7,352	8,056	8,124	8,522	8,861	9,290
Conventional Thermal	125	56	94	115	125	180	278	501	679	636
Hydroelectric	5,084	5,617	5,597	5,871	5,864	6,421	6,502	6,535	6,701	7,313
Geothermal	764	927	937	1,065	874	937	1,091	1,154	1,177	1,075
Wind	96	166	170	242	219	243	194	260	229	188
Solar, Tidal and Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	4	16	15	50	270	275	60	71	75	78
Net Consumption* (GWh)	5,472	5,834	6,064	6,185	6,649	6,937	7,310	7,746	8,117	8,247
Imports	1	22	130	35	100	202	81	149	203	96
Exports	128	497	379	478	273	440	70	60	40	166
Electricity Distribution Losses	474	473	500	715	530	881	825	865	908	973
Carbon Dioxide Emissions (Million Metric Tons of CO_2) Consumption of Fossil Fuels	5.14	5.01	5.22	5.39	5.95	5.72	5.65	6.64	7.22	7.14

Notes:

NA = Information not available

* Net generation + electricity imports - electricity exports - electricity distribution losses.

Source: U.S. Energy Information Agency http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm

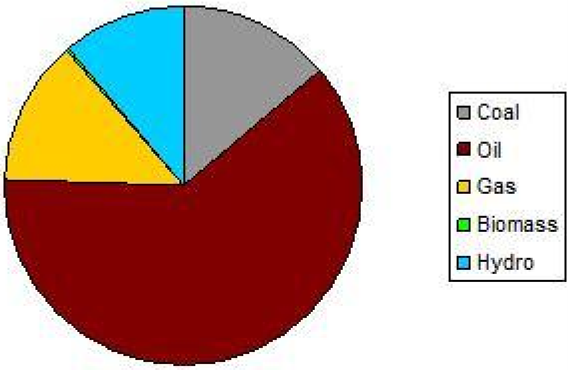
Governmental authority for energy policy lies with the Ministry for Environment and Energy (MINAE). MINAE leads the Consejo Subsectoral de Energía, which is composed of the most important institutions and state-run enterprises in the energy sector, including the Ministry of Science and Technology, the Ministry of Planning and Economic Policy, the regulatory authority ARESEP, the national oil company RECOPE and the national electrical utility ICE. The independent regulatory authority ARESEP was created in 1996 and is responsible for determining transit fees and electricity prices.

2.2. Dominican Republic

Dominican Republic relies heavily upon thermal power plants fueled by imported fossil fuels for the generation of electric power (Figure B-2). Sixty-two percent of its electricity is generated from burning oil, 14 percent from coal and 13 percent from natural gas. Only 11 percent is generated by hydroelectric facilities and less than one percent by the burning of biomass.

Although the amount of electricity generated has grown 70 percent in the past 10 years, the contribution from hydroelectric sources has remained relatively constant, with the growth being achieved through the development of additional conventional thermal capacity reliant upon imported fossil fuels (Tale B-4).

Figure B- 2: Dominican Republic energy generation by fuel type 2008



Source of data: Table B-2

Table B- 4: Dominican Republic energy trends 1998-2008

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Petroleum Products (1,000 Barrels/Day)										
Total Consumption	99.24	110.06	113.95	116.15	115.28	114.07	115.41	116.73	118.72	120.00
Fuel Oil Consumption	52.78	66.23	67.80	75.97	64.37	59.72	58.93	60.16	61.96	NA
Proved Reserves (Billion Barrels)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas (Billion Cubic Feet)										
Consumption	0.0	0.0	0.0	0.0	10.6	4.6	8.8	8.8	0.0	17.0
Proved Reserves (Billion Barrels)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal (Million Short Tons)										
Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Consumption	0.3	0.1	0.2	0.3	1.2	0.9	0.5	0.9	0.8	1.0
Electricity Net Generation (GWh)	8,562	8,064	9,717	10,863	12,740	13,014	12,221	13,389	14,036	14,577
Conventional Thermal	7,439	7,274	9,130	9,957	11,509	11,381	10,316	11,619	12,267	12,838
Hydroelectric	1,088	754	551	869	1,188	1,566	1,877	1,742	1,733	1,711
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar, Tidal and Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	35	36	36	37	43	67	28	28	36	28
Net Consumption* (GWh)	6,459	5,784	8,480	9,482	11,415	11,658	11,419	11,823	12,720	12,866
Imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Exports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electricity Distribution Losses	2,103	2,280	1,237	1,381	1,325	1,356	802	1,566	1,316	1,711
Carbon Dioxide Emissions (Million Metric Tons of CO_2) Consumption of Fossil Fuels	14.36	15.80	16.59	17.14	19.54	18.12	17.44	18.43	19.16	19.40

Notes:

NA = Information not available

* Net generation + electricity imports - electricity exports - electricity distribution losses.

Source: U.S. Energy Information Agency http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm

The National Energy Commission (Comisión Nacional de la Energía, CNE) is the government agency responsible for energy policy in Dominican Republic. The Electricity Superintendence (Superintendencia de Electricidad, SIE) is the regulatory agency, while the Coordination Agency (Organismo Coordinador, OC) has the responsibility to coordinate the dispatch of electricity.

Dominican Corporation of State Electricity Companies (Corporación Dominicana de Empresas Eléctricas Estatales - CDEEE) is a holding company that brings together all of the electricity generation, transmission and distribution companies owned or partially owned by the government as well as government electricity programs. CDEEE consists of:

- Empresa de Generación Hidroeléctrica Dominicana (EGEHID - Hydroelectricity Generation Company)
- Empresa de Transmisión Eléctrica Dominicana (ETED - Electricity Transmission Company)
- Unidad de Electrificación Rural y Suburbana (UERS - Rural and Suburban Electrification Unit)
- Programa de Reducción de Apagones (PRA - Blackout Reduction Program)
- 50 percent of the North Distribution Company, EdeNorte
- 50 percent of the South Distribution Company, EdeSur
- 50 percent of the East Distribution Company, EdeEste

EdeNorte and EdeSur are entirely government-owned, the remaining 50 percent shares being held by the government's Enterprise Trust Fund, Fondo Patrimonial de las Empresas (FONPER). EdeEste is a mixed private-public company.

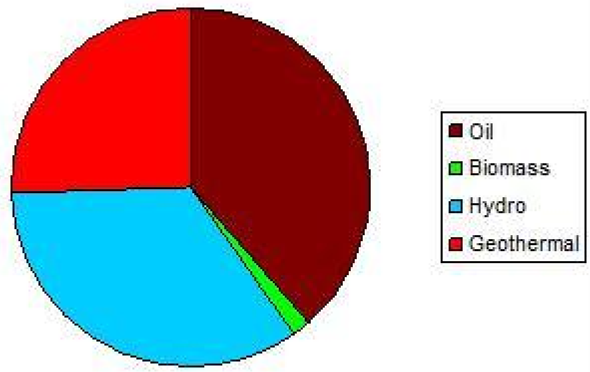
Eighty-six percent of the generation capacity is privately owned and 14 percent is publicly owned. All of the hydroelectric facilities are publicly owned, and all of the other plants are privately owned, by eleven private companies. The transmission system is owned by ETED, a government-owned company. It consists of 940 km of 138kV single-line circuit lines that radiate from Santo Domingo to the north, east, and west. There are three distribution companies, two wholly-owned by the government (EdeNorte and EdeSur) and another which is a 50/50 private-public enterprise (EdeEste).

2.3. El Salvador

Electric power in El Salvador is generated primarily by three sources: conventional thermal plants fueled by oil (39%), hydroelectric power (34%) and geothermal energy (25%) (Figure B-3). Biomass provides only two percent of the total electric power generated.

In 1999 hydroelectric power generated 48 percent of total electric power (Table B-5). Since that time, power generation has grown by 56 percent, with most of the growth occurring in the development of geothermal power, which has nearly tripled its contribution to total generation since 1999, making El Salvador the largest producer of

Figure B- 3: El Salvador energy generation by fuel type 2008



Source of data: Table B-2

geothermal generated electrical power in the CAFTA-DR region. The 2007 National Energy Strategy determined that potential geothermal capacity in El Salvador is about 450MW, or slightly more than double the current capacity.

Table B- 5: El Salvador energy trends 1998-2008

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Petroleum Products (1,000 Barrels/Day)										
Total Consumption	38.31	38.06	39.41	39.01	42.36	41.93	43.36	43.80	44.20	42.00
Fuel Oil Consumption	21.94	21.88	22.80	23.89	23.95	22.94	23.88	23.57	24.38	NA
Proved Reserves (Billion Barrels)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas (Billion Cubic Feet)										
Consumption	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proved Reserves (Billion Barrels)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal (Million Short Tons)										
Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Consumption	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electricity Net Generation (GWh)	3,659	3,687	3,742	3,923	4,196	4,262	4,586	5,370	5,560	5,721
Conventional Thermal	1,319	1,757	1,653	1,830	1,747	1,904	1,909	2,313	2,438	2,160
Hydroelectric	1,749	1,163	1,152	1,128	1,451	1,374	1,652	1,942	1,722	2,018
Geothermal	568	747	918	943	975	960	998	1,083	1,313	1,443
Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar, Tidal and Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	23	20	19	22	23	24	26	32	87	100
Net Consumption* (GWh)	3,411	3,972	3,888	3,769	3,960	4,069	4,255	4,648	5,200	5,608
Imports	460	900	700	430	433	466	322	11	38	83
Exports	208	112	44	51	103	84	38	9	7	89
Electricity Distribution Losses	500	503	510	533	566	575	615	724	391	107
Carbon Dioxide Emissions (Million Metric Tons of CO_2) Consumption of Fossil Fuels	5.48	5.51	5.70	5.77	6.08	6.02	6.21	6.23	6.32	5.93

Notes:
NA = Information not available
* Net generation + electricity imports - electricity exports - electricity distribution losses.
Source: U.S. Energy Information Agency http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm

Hydroelectric generation is almost totally owned and operated by a public company, the Comisión Hidroeléctrica del Río Lempa (Lempa River Hydroelectric Commission – CEL). All other forms of electric power generation are in private hands. In 2006, there were 11 private companies generating electricity in El Salvador at 18 facilities.

One government-owned company, Empresa Transmisora de El Salvador, is responsible for the maintenance and expansion of the transmission system. Distribution is controlled by five privately-owned companies. The market share for each of them in 2006 was:

- CAESS: 44 percent
- Delsur: 25 percent
- CLESA: 18 percent
- Empresa Eléctrica de Oriente (EEO): 10 percent
- Distribuidora Eléctrica de Oriente (Deusem): 2 percent

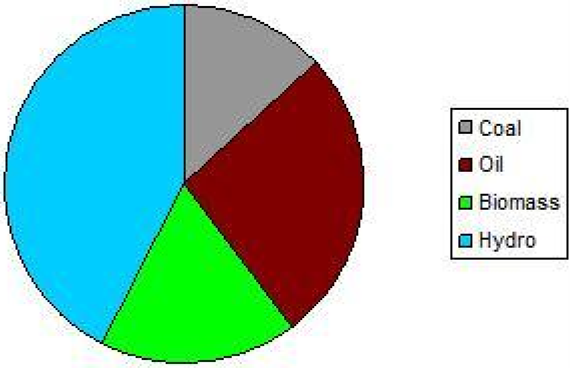
CAESS, CLESA, EEO and Deusem are controlled by AES Corporation.

The government of El Salvador plans for and regulates electrical power generation and transmission through three governmental entities. The Dirección de Energía Eléctrica (Electrical Energy Directorate is the administrative unit within the Ministry of Economy responsible for elaborating, proposing, coordinating and executing policies, programs, projects and other actions in the electricity sector. The General Superintendence of Electricity and Telecommunications is in charge of regulating the power market, the distribution companies and consumer prices. In 2006, the President created the National Energy Council to analyze the energy situation and Government proposals, recommend new actions and strategies, and promote the use of renewable energy and efficient use of energy.

2.4. Guatemala

Thermal electric plants fueled by fossil fuels and hydroelectric power provide most of Guatemala's electrical power (Figure B-4). Hydroelectric power generates 42 percent of the total power, oil 27 percent and coal 13 percent. Although Guatemala is the only CAFTA-DR country with proven oil reserves (Table B-6), the amount of the reserves are insignificant compared to the amount of petroleum products consumed in the country, so all of the coal used for energy generation and nearly all of the oil is imported.

Figure B- 4: El Salvador energy generation by fuel type 2008



Source of data: Table B-2

Central America's first coal-fired power plant, the 120-MW San Jose Power Station, opened in Guatemala in December 1999. Owners include Teco Power Services, Coastal Power Company and Compania de Centroamerica. The plant began operations in early 2000, burning low-sulfur South American coal. It is located about 75 miles south of Guatemala City.

The combustion of biomass provided 18 percent of the total electric power in Guatemala in 2008, the highest contribution by biomass of all of the CAFTA-DR countries. The amount of electricity generated by biomass grew by 70 percent in the four years period between 2004 and 2008.

Table B- 6: Guatemala energy trends 1998-2008

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Petroleum Products (1,000 Barrels/Day)										
Total Consumption	59.16	59.29	65.90	64.56	64.98	67.57	70.29	71.40	72.00	68.00
Fuel Oil Consumption	34.52	32.01	36.33	35.69	37.52	38.82	40.05	39.11	42.74	NA
Proved Reserves (Billion Barrels)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.1	0.1
Natural Gas (Billion Cubic Feet)										
Consumption	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proved Reserves (Billion Barrels)	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	NA	NA
Coal (Million Short Tons										
Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Consumption	0.0	0.2	0.2	0.4	0.4	0.5	0.4	0.5	0.7	0.7
Electricity Net Generation (GWh)	4,988	5,808	5,608	5,910	6,328	6,763	7,299	7,643	8,425	8,395
Conventional Thermal	2,120	2,740	2,897	3,423	3,043	3,483	3,220	2,894	3,531	3,246
Hydroelectric	2,061	2,263	1,906	1,682	2,480	2,453	3,228	3,795	3,590	3,675
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar, Tidal and Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	807	805	805	805	805	827	851	954	1,304	1,474
Net Consumption* (GWh)	3,974	3,610	4,020	4,151	5,674	6,076	6,379	6,615	7,116	7,108
Imports	245	123	95	55	31	41	23	8	8	5
Exports	465	827	336	440	428	464	339	90	132	76
Electricity Distribution Losses	794	1,494	1,347	1,374	257	264	604	946	1,186	1,216
Carbon Dioxide Emissions (Million Metric Tons of CO_2) Consumption of Fossil Fuels	8.69	9.06	10.01	10.27	10.25	10.85	11.54	11.22	12.31	11.56

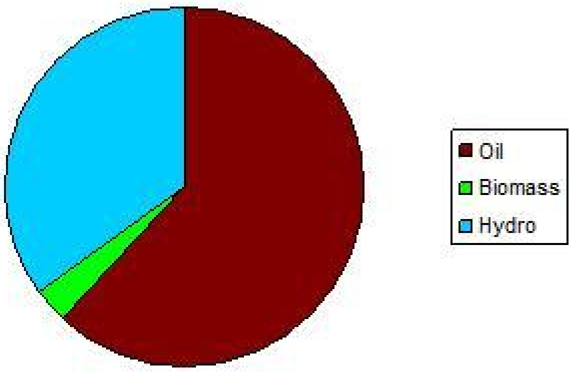
Notes:
NA = Information not available
* Net generation + electricity imports - electricity exports - electricity distribution losses.
Source: U.S. Energy Information Agency http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm

2.5. Honduras

Thermal power plants fired by oil generated 62 percent of Honduras' total electricity in 2008, with hydroelectric power providing 35 percent and biomass combustion providing only 2 percent (Figure B-5). Power generated by hydroelectricity has remained relatively constant since 1999, so that nearly all of the 100 percent increase in electricity generation in the past 10 years has been met by expansion of oil-fueled thermal power (Table B-7).

The Empresa Nacional de Energía Eléctrica (ENEE) is the national utility in Honduras. It is the owner of nearly all of the hydroelectric capacity in the country and about eight percent of the thermal capacity. ENNE owns and operates six hydroelectric facilities[3]:

Figure B- 5: Honduras energy generation by fuel type 2008



Source of data: Table B-2

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[3] These capacity values and those in the following paragraphs come from ENNE (2011).

- Francisco Morazán (also called El Cajón) 300 MW of capacity
- Río Lindo 80 MW of capacity
- Nacaome 30 MW of capacity
- Cañaveral 29 MW of capacity
- El Níspero 22.5 MW of capacity
- El Coyolar 1.6 MW of capacity
- Santa María del Real 1.3 MW of capacity

It has an additional 124.6 MW of capacity in 6 small fossil-fuel powered plants ranging in size from 5 to 30 MW. In addition to producing energy, it purchases electricity, sells electricity to customers, and is solely responsible for its transmission and distribution (except in some instances of small isolated systems).

Table B- 7: Honduras energy trends 1998-2008

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Petroleum Products (1,000 Barrels/Day)										
Total Consumption	30.63	28.11	33.00	36.34	36.54	41.85	44.09	46.10	47.50	48.00
Fuel Oil Consumption	20.74	18.07	22.67	27.57	26.16	31.68	33.04	33.45	36.27	NA
Proved Reserves (Billion Barrels)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas (Billion Cubic Feet)										
Consumption	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proved Reserves (Billion Barrels)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal (Million Short Tons)										
Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Consumption	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.2	0.3
Electricity Net Generation (GWh)	3,097	3,546	3,747	3,926	4,351	4,638	5,318	5,728	6,069	6,261
Conventional Thermal	987	1,308	1,853	2,317	2,593	3,199	3,480	3,544	3,717	3,806
Hydroelectric	2,109	2,237	1,885	1,595	1,724	1,387	1,701	2,049	2,192	2,268
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar, Tidal and Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	1	1	9	14	34	52	137	135	160	187
Net Consumption* (GWh)	2,514	3,139	3,210	3,411	3,654	3,925	4,014	4,208	4,714	4,903
Imports	150	315	310	400	331	408	58	19	12	0.0
Exports	6	5	0.0	0.0	0.0	15	2	11	0.0	12
Electricity Distribution Losses	727	717	847	915	1,028	1,107	1,360	1,528	1,366	1,346
Carbon Dioxide Emissions (Million Metric Tons of CO_2) Consumption of Fossil Fuels	4.86	4.58	5.31	5.96	6.00	7.01	7.27	7.82	8.63	8.21

Notes:
NA = Information not available
* Net generation + electricity imports - electricity exports - electricity distribution losses.
Source: U.S. Energy Information Agency http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm

Agreements that ENEE has signed with Independent Power Producers operating power plants now account for the majority of energy generation in Honduras. Five large companies generate most of this electricity:

- LUFUSSA 39.5 MW of capacity, gas turbine; 347.4 MW of capacity, diesel
- ENERSA con 276.1 MW of capacity, diesel
- ELCOSA 80 MW of capacity, diesel
- EMCE 55 MW of capacity, diesel

There are five addition companies that have a total fossil-fuel fired thermal capacity of 69.9 MW at facilities that range in size from 8 to 21.8 MW of capacity. There are also 13 small privately owned and operated hydroelectric facilities ranging in size from 0.5 to 12.8 MW of capacity with a total capacity of 62 MW and 11 small privately operated biomass-fueled thermal plants ranging in size from 0.5 to 25.8 MW with a total capacity of 91.4 MW.

The Electricity Law of 1994 assigns the policymaking function for electric power to an Energy Cabinet chaired by the President of the Republic with the with the Secretaría de Recursos Naturales y Ambiente (SERNA) as its secretary and coordinator. A regulatory agency, the Comisión Nacional de Energía (CNE), was created, among other functions:

- Supervise power sales agreements to be signed by distribution companies;
- Approve standards related to service quality, reliability and safety;
- Monitor and enforce laws and standards;
- Approve tariffs and propose Average Short-Term Marginal costs;
- Approve system expansion programs;
- Submit for approval to the Ministry of Environment power purchase and sales agreements that ENEE intends to sign.

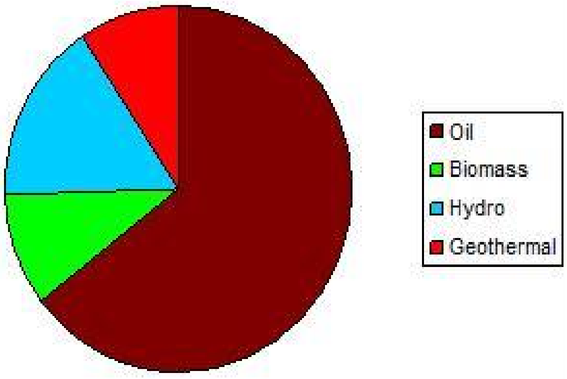
The Energy Cabinet has met less than once a year since its creation. CNE has had a marginal role due to lack of political support and resources. As a result, has become the lead government entity in regards to policymaking and regulation, as well as being the regulated entity. ENEE is governed by a Board of Directors, which is formed by Minister of Natural Resources and the Environment, who also chairs the Board; the Minister of Public Works, Transportation and Housing; the Minister of Finance; the Minister of Industry and Commerce; the Minister of Foreign Cooperation; and a representative of the Honduran Council of Private Enterprise (COHEP). The Board appoints a General Manager, who acts as its Secretary but has no vote.

2.6. Nicaragua

Nicaragua, like Dominican Republic and Honduras, is heavily reliant upon oil-fired thermal plants to generate electricity (Figure B-6). In 2008, oil produced 64 percent of the total electric power. All of the oil is imported (Table B-8). The other 36 percent is generated by hydroelectric power (16%), geothermal and the combustion of biomass (10% each).

As in the rest of the region, the generation of electricity has grown significantly in Nicaragua in the past 10 years (65%). Most of the increase has been met by expanding the reliance on oil-fired thermal plants; however, 2008 saw an increase in both hydroelectric power and geothermal which allowed a decrease in reliance upon oil for electric power generation.

Figure B- 6: Nicaragua energy generation by fuel type 2008



Source of data: Table B-2

Nicaragua is the country in the CAFTA-DR region with the lowest level of electricity generation. It is more dependent than the other Central American countries on imported oil for electricity generation, which supplied 64 percent of its electrical power in 2008. This has led to some shortages when oil prices rise, as was the case in 2006.

Nicaragua's power sector underwent a deep restructuring during the late 1990s, with the new Electricity Law (April 1998 - Ley No.272) allowing for privatization of the generation and distribution activities previously controlled by the state-owned Empresa Nicaraguense de Electricidad. As a result, two State-owned enterprises and 12 private companies operate 23 electrical energy generating facilities in Nicaragua (Table B-8). Government-owned enterprises maintained control of the large hydroelectric facilities and two large thermal plants, which no private companies were interested in acquiring. One company, Dissur-Disnorte, owned by the Spanish Unión Fenosa, controls 95 percent of the distribution. Transmission, however, is owned and managed by the state-owned company, Empresa Nacional de Transmisión Eléctrica.

Table B- 8: Generating capacity by type and company for 2009

Type	Company Name	Number of Plants	Installed Capacity (MW)
Public		**4**	**226.8**
Thermal	Eléctrica Central S.A. (GECSA)	1	57.4
Gas Turbine	GECSA	1	65.0
Hydroelectric	Hidroeléctrica S.A. (HIDROGESA)	2	104.4
Private		**19**	**742.3**
Conventional Thermal	ALBANISA	7	175.6
	Generadora Eléctrica de Occidente S.A. (GEOSA)	1	106.0
	Empresa Energética Corinto (EEC)	1	74.0
	Corporación Eléctrica Nicaragüense, S.A. (CENSA)	1	63.9
	Tipitapa Power	1	52.2
	Generadora San Rafael	1	6.4
Gas Turbine	GEOSA	1	14.0
Hydroelectric	Atder-BL	1	0.9
Biomass Thermal	Monte Rosa, SA	1	62.5
	Nicaragua Sugar Estates Limited (NSEL)	1	59.3
Geothermal	Ormat Momotombo Power Company	1	77.5
	Polaris Energy Nicaragua, S.A. (PENSA)	1	10.0
Wind	Consorcio Eólica, S.A. (AMAYO)	1	40.0
TOTAL		**23**	**969.1**

Source: Instituto Nicaragüense de Energía website
http://www.ine.gob.ni/DGE/estadisticas/serieHistorica/Capacidad_Instalada_2009.pdf

Biomass projects in Nicaragua use by-products from the sugar cane industry to fuel thermal plants. The NSEL plant began operation in 1998 and burns bagasse, the fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice. The Monte Rosa plant began operation in and burns biogas made from vinasse, the still bottoms left after distillation of fermented sugarcane.

Nicaragua saw the operation of its first wind power generating facility in 2009, the Consorcio Eólica, S.A. that has the capability of generating 40 MW.

Three government agencies are involved in planning for and regulating the generation, transmission and distribution of electric power. The Ministerio de Energía y Minas is in charge of formulating policies and strategies for the energy sector. The Instituto Nicaragüense de Energía is the regulatory agency, awarding concessions for transmission and distribution, and approving tariffs. The Centro Nacional de Despacho de Carga, a division of ENTREL, is in charge of regulating the transmission and distribution of electricity.

Table B- 9: Nicaragua energy trends 1998-2008

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Petroleum Products (1,000 Barrels/Day)										
Total Consumption	23.96	24.02	25.58	25.42	25.64	27.17	28.60	27.40	27.80	28.00
Fuel Oil Consumption	17.29	17.29	18.34	17.14	16.33	17.49	18.24	19.20	19.11	NA
Proved Reserves (Billion Barrels)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas (Billion Cubic Feet)										
Consumption	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proved Reserves (Billion Barrels)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal (Million Short Tons)										
Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Consumption	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Electricity Net Generation (GWh)	2,076	2,156	2,341	2,646	2,562	2,673	2,946	3,023	3,286	3,419
Conventional Thermal	1,538	1,754	1,905	2,098	1,913	1,996	2,107	2,293	2,393	2,263
Hydroelectric	389	208	195	300	294	318	427	300	301	529
Geothermal	97	127	196	200	257	242	258	295	231	306
Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar, Tidal and Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	52	67	45	48	98	117	155	135	362	321
Net Consumption* (GWh)	1,577	1,585	1,613	1,880	1,759	1,985	2,342	2,424	2,570	2,646
Imports	80	114	17	16	12	23	25	53	64	28
Exports	22	1	0.0	7	21	22	8	0.0	0.0	0.0
Electricity Distribution Losses	557	684	745	775	794	689	621	652	780	801
Carbon Dioxide Emissions (Million Metric Tons of CO_2) Consumption of Fossil Fuels	3.74	3.70	3.94	4.05	4.11	4.42	4.60	4.76	4.71	4.50

Notes:
NA = Information not available
* Net generation + electricity imports - electricity exports - electricity distribution losses.
Source: U.S. Energy Information Agency http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm

APPENDIX C. REQUIREMENTS AND STANDARDS: CAFTA-DR COUNTRIES, OTHER COUNTRIES, AND INTERNATIONAL ORGANIZATIONS

This Appendix summarizes a range of quantitative benchmarks for specific environmental requirements of new energy projects beyond the requirement to develop an EIA and mitigate and avoid adverse environmental impacts. It does not attempt to capture non-quantitative practice standards. The benchmark standards contained within this Appendix include ambient quality and sector-specific performance standards from CAFTA-DR countries, including the United States, other foreign governments, and international organizations. CAFTA-DR country EIA reviewers and preparers might use this information in the absence of such standards or to assess the validity and to evaluate the significance of impacts within EIAs.

The Appendix includes:

- Introduction to Environmental Laws, Standards, and Requirements
- Ambient Standards for Air and Water Quality
- Energy-Sector Specific Performance Standards
    - Water Discharge/Effluent Limits
    - Storm Water Runoff
    - Air Emission Limits
    - Solid Waste
- International Treaties and Agreements Ratified/Signed
- Website References

Section 1 provides a general introduction on the role of environmental regulatory approaches to reduce or prevent pollution directly or indirectly, Section 2 summarizes ambient freshwater, drinking water, and air quality standards for the CAFTA-DR countries, including the United States and the International Finance Corporation/ World Bank Group. Section 3 provides an overview of performance standards applicable to energy-production-related projects; Section 3.1 summarizes water discharge/effluent limits; Section 3.2 provides supplemental information about water discharge/effluent limits in the United States; Section 3.3 summarizes storm water runoff discharge/effluent limits; Section 3.4 summarizes air emission limits; and Section 3.5 summarizes solid waste discharge/effluent limits. Section 4 summarizes international treaties and agreements ratified or signed by CAFTA DR Countries and Section 5 provides links to relevant websites. To the extent possible, footnotes provide necessary caveats but it is strongly recommended that if this information is used, the reviewer or preparer confirm it is up to date and appropriate for the circumstances.

1 INTRODUCTION TO ENVIRONMENTAL LAWS, STANDARDS, AND REQUIREMENTS

There are many approaches to managing environmental problems (see Figure C-1). Some approaches are purely voluntary – that is, they encourage and assist change but do not require it. Other approaches are regulatory – that is, they require change or specific performance expectations. At the heart of regulatory approaches are environmental requirements-specific practices and procedures required by law to directly or indirectly reduce or prevent pollution. Figure C-2 lists some examples of the types of requirements and standards typically used for environmental management, including:

- Ambient Standards
- Performance Standards (Emissions and Effluents).
- Technology Standards

- Practice Standards
- Information Requirements
- Product or Use Bans

While wholly regulatory (command-and-control) approaches generally have the most extensive requirements of all the management options, most of the other options, including market-based economic incentive, labeling, and liability-based approaches, introduce some form of requirements.

Requirements may be general or facility/activity specific. General requirements are most frequently implemented in the form of (1) laws, (2) regulations, or (3) general permits or licenses that apply to a specific class of facilities. General requirements may apply directly to a group of facilities or they may serve as a basis for developing facility-specific requirements. Facility-specific requirements are usually implemented in the form of permits or licenses, or, in the case of environmental impact assessment, may become legally binding commitments if they are a) within the environmental impact assessment itself, b) within a separate environmental management plan or monitoring/mitigation plan, or c) incorporated into a separate contract.

Appendix C benchmarks only quantitative limits in a highly summarized format as a useful point of reference. For additional background on enforceable requirements, see the International Network for Environmental Compliance and Enforcement Website: http://www.inece.org and specifically the resource library www.inece.org/library/principles.html. Others references for more details behind the limits summarized in the Appendix are provided in the last section.

Figure C- 1: Approaches to environmental management

Voluntary Approaches

Voluntary approaches encourage or assist, but do not require, change. Voluntary approaches include public education, technical assistance, and the promotion of environmental leadership by industry and nongovernment organizations. Voluntary approaches may also include some management of natural resources (e.g., lakes, natural areas, ground water) to maintain environmental quality.

Regulatory (Command-and-Control) Approaches

In command-and-control approaches, the government prescribes the desired changes through detailed requirements and then promotes and enforces compliance with these requirements. Table 3-2 describes types of requirements typically used in command-and-control approaches.

Market-based/Economic Incentive Approaches

Market-based/economic incentive approaches use market forces to achieve desired behavior changes. These approaches can be independent of or build upon and supplement command-and-control approaches. For example, introducing market forces into a command-and-control approach can encourage greater pollution prevention and more economic solutions to problems. Market-based/economic incentive approaches include:

- Fee systems. In this approach, the government taxes emissions, effluents, and other environmental releases.
- Tradeable permits. In this approach, companies trade permitted emission rights with other companies.
- Offset approaches. These approaches allow a facility to propose various approaches to meeting an environmental goal. For example, a facility may be allowed to emit greater quantities of a substance from one of its operations if the facility offsets this increase by reducing emissions at another of its operations.
- Auctions. In this approach, the government auctions limited rights to produce or release certain environmental pollutants.
- Environmental labeling/public disclosure. In this approach, manufacturers are required to label products so that consumers can be aware of the environmental impacts of the products. Consumers can then choose which products to purchase based on the products' environmental performance.

Risk-based Approaches

Risk-based approaches to environmental management are relatively new. These approaches establish priorities for change based on the potential for reducing the risks posed to public health and/or the environment.

Pollution Prevention

The goal of pollution prevention approaches is to prevent pollution by reducing or eliminating generation of pollution at the source. The changes needed to prevent pollution can be required, e.g., as part of a command-and-control approach, or encouraged as voluntary actions.

Liability

Some environmental management approaches are based on laws that make individuals or businesses liable for the results of certain actions or for damages they cause to another individual or business or to their property. Liability systems do not have explicit requirements. However, implicit requirements often develop as cases are brought to court and patterns are established about what activities justify which consequences. To be effective, liability systems generally need some enforcement by the government, nongovernment organizations, or individuals to gather evidence and develop legal cases. Examples of liability-based environmental management systems include nuisance laws, laws requiring compensation for victims of environmental damage, and laws requiring correction of environmental problems caused by improper disposal of hazardous waste. Liability systems reduce or prevent pollution only to the extent that individuals or facilities fear the consequences of potential legal action against them.

Source: Wasserman, Cheryl et. al., Principles of Environmental Enforcement, U.S. Environmental Protection Agency, July, 1992.

Figure C- 2: Examples of environmental requirements

Ambient Standards

Ambient standards (also called media quality standards) are goals for the quality of the ambient environment (e.g., air, water). Ambient standards are usually written in units of concentration (e.g., the level of nitrogen dioxide in the air cannot exceed 0.053 parts per million). In the U.S., ambient standards are used as environmental quality goals and to plan the level of emissions from individual sources that can be accommodated while still meeting the area wide goal. Ambient standards may also be used as triggers, e.g., when the standard is exceeded, monitoring or enforcement efforts are increased. Enforcement of ambient standards usually requires relating an ambient measurement to emissions or activities at a specific facility. This can be difficult.

Performance Standards (Emissions and Effluents)

These standards are widely used for regulations, permits, and monitoring requirements. Performance standards limit the amount or rate of particular chemicals or discharges that a facility can release into the environment in a given period of time. Performance standards provide flexibility because they allow sources to choose which technologies they will use to meet the standards. Often such standards are based on the output that can be achieved using the best available control technology. Some requirements introduce additional flexibility by allowing a source with multiple emissions to vary its emissions from each stack as long as the total sum of the emissions does not exceed the permitted total. Compliance with emission standards is measured by sampling and monitoring. Depending on the kind of instruments required, compliance can be difficult and/or expensive to monitor.

Technology Standards

These standards require the regulated community to use a particular type of technology (e.g., the "best available technology") to control and/or monitor emissions. Technology standards are particularly appropriate when the equipment is known to perform well under the range of conditions generally experienced by sources in the community. It is relatively easy for inspectors to determine whether sources are in compliance with technology standards: the approved equipment must be in place and operating properly. It may be difficult, however, to ensure that the equipment is operating properly over a long period of time. Technology standards can inhibit technological innovation and pollution prevention. In the U.S. many air performance standards are based on the performance of a particular technology or technologies, but sources are not required to actually use that technology to meet the performance standards.

Practice Standards

These standards require or prohibit certain work activities that have significant environmental impacts. For example, a standard might prohibit carrying hazardous liquids in uncovered buckets. Like technology standards, it is easy for program officials to inspect for compliance and take action against noncomplying sources, but difficult to ensure ongoing compliance.

Information Requirements

These requirements are different from the standards described above in that they require a source of potential pollution (e.g., a pesticide manufacturer or facilities involved in generating, transporting, storing, treating, and disposing of hazardous waste) to develop and submit information to the government. Sources generating pollution may be required to monitor, report on, and maintain records of the level of pollution generated and whether or not it exceeds performance standards. Information requirements are often used when the potential pollution source is a product such as a new chemical or pesticide, rather than a waste. For example, a manufacturer may be required to test and report on a product's potential to cause harm if released into the environment.

Product or Use Bans

A ban may prohibit a product outright (e.g., ban the manufacture, sale, and/or use of a product) or may prohibit particular uses of a product.

Source: Wasserman, Cheryl et. al. Principles of Environmental Enforcement, U.S. Environmental Protection Agency, July, 1992.

2 AMBIENT STANDARDS FOR AIR AND WATER QUALITY

The following Tables summarize and compare standards across countries and institutions for:

- Freshwater Quality Guidelines and Standards
- Drinking Water Quality Guidelines and Standards
- Ambient Air Quality Guidelines and Standards

Table C- 1: Freshwater quality guidelines and standards

Pollutant	United States		European Union	
	National Recommended Water Quality Criteria[1]		Annual Average Value (Inland surface Waters) (µg/l)	Maximum Allowable Concentration (Inland surface Waters) (µg/l)
	Maximum Concentration (CMC) (µg/l)	Continuous Concentration (CCC) (µg/l)		
Alachlor			0.3	0.7
Anthracene			0.1	0.4
Arsenic	340	150		
Atrazine			0.6	2.0
Benzene			10	50
Benzo(a)pyrene			0.05	0.1
Brominated diphenylether			0.0005	N/A
Cadmium	2	0.25	≤ 0.08 (Class 1)[2] 0.08 (Class 2) 0.09 (Class 3) 0.15 (Class 4) 0.25 (Class 5)	≤ 0.45 (Class 1) 0.45 (Class 2) 0.09 (Class 3) 0.15 (Class 4) 0.25 (Class 5)
C 10-13 Chloralkanes			0.4	1.4
Chlordane	2.4	0.0043		
Chlorfenvinphos			0.1	0.3
Chloride	860,000	230,000		
Chromium (III)	570	74		
Chromium (VI)	16	11		
Chlorpyrifos (Chlorpyrifos-ethyl)			0.03	0.1
Cyanide	22	5.2		
DDT total			0.025	N/A
Para-para-DDT			0.01	N/A
1,2-Dichloroethane			10	N/A
Dichloromethane			20	N/A
Dieldrin	0.24	0.056	∑=0.01 [3]	N/A
Di(2-ethylexyl)-phthalate (DEPH)			1.3	N/A
Diuron			0.2	1.8

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[1] In the United States, the federal government issues recommended water quality criteria to provide for the protection and propagation of fish, shellfish, and wildlife and for recreation in and on the water but it is up to the states, in the first instance, to adopt binding water quality criteria based on designated use categories.

[2] For cadmium and its compounds the EQS values vary depending on the hardness of the water as specified in five class categories (Class 1: < 40 mg CaCO3/l,Class 2: 40 to < 50 mg CaCO3/l, Class 3: 50 to < 100 mg CaCO3/l, Class 4: 100 to < 200 mg CaCO3/l and Class 5: ≥ 200 mg CaCO3/l).

[3] Sum for cyclodiene pesticides which include: Aldrin, Dieldrin, Endrin, Isodrin

Pollutant	United States		European Union	
	National Recommended Water Quality Criteria[1]		Annual Average Value (Inland surface Waters) (µg/l)	Maximum Allowable Concentration (Inland surface Waters) (µg/l)
	Maximum Concentration (CMC) (µg/l)	Continuous Concentration (CCC) (µg/l)		
alpha-Endosulfan	0.22	0.056	0.005	0.01
beta-Endosulfan	0.22	0.056	0.005	0.01
Endrin	0.086	0.036	∑=0.01[4]	N/A
Fluoranthene			20	N/A
Heptachlor	0.52	0.0038		
Heptachlor Epoxide	0.52	0.0038		
Hexachloro-benzene			0.01	0.05
Hexachloro-butadiene			0.1	0.6
Hexachloro-cyclohexane			0.02	0.04
Isoproturon			0.3	1.0
Lead	65	2.5	7.2	N/A
Mercury	1.4	0.77	0.05	0.07
Naphthalene			2.4	N/A
Nickel	470	52	20	N/A
Nonylphenol (4-Nonylphenol)			0.3	2.0
Octylphenol			0.1	N/A
Pentachloro-benzene			0.007	N/A
Pentachlorophenol	19	15	0.4	1.0
Polychlorinated Biphenyls (PCBs)		0.014		
Selenium		5		
Simazine			1.0	4.0
Silver	3.2			
Sulphate			129.75 mg/l	4,200 mg/l
Tetrachloroethylene			10.0	N/A
Trichloroethylene			10	N/A
Toxaphene	0.73	0.0002		
Tributyltin compounds			0.0002	0.0015
Trichloro-benzenes			0.4	N/A
Trichloro-methane			2.5	N/A
Trifluralin			0.03	N/A
Zinc	120	120		

Sources: US: http://www.epa.gov/waterscience/criteria/wqctable/index.html#cmc
EU: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:348:0084:0097:EN:PDF

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[4] Sum for cyclodiene pesticides which include: Aldrin, Dieldrin, Endrin, Isodrin

Table C- 2: Drinking water quality guidelines and standards

Pollutant	United States		Canada	European Community	Czech Republic	World Health Organization
	Maximum Contaminant Level Goal	Maximum Contaminant Level	Maximum Acceptable Concentration	Parametric Value	Parametric Value	Guideline Value
Acrylamide				0.1 µg/l	0.1 µg/l	
Ammonium				0.50 mg/l	0.50 mg/l	
Aluminum			0.1/0.2 mg/l (100-200 µg/l)	200 µg/l	200 µg/l	
Antimony	0.006 mg/l (6 µg/l)	0.006 mg/l	0.006 (6 µg/l)	5.0 µg/l	5.0 µg/l	
Arsenic	0	0.01 mg/l	0.1 mg/l (10 µg/l)	10 µg/l	10 µg/l	10 µg/l
Asbestos	7 million fibers/liter	7 million fibers/liter				
Barium	3 mg/l (2000 µg/l)	2 mg/l (2000 µg/l)	1 mg/l (1000 µg/l)			
Benzene			0.005 mg/l (5 µg/l)	1.0 µg/l	1.0 µg/l	
Benzo(a)pyrene			0.00001 mg/l (0.01 µg/l)	0.010 µg/l	0.010 µg/l	
Beryllium	0.004 mg/l (4 µg/l)	0.004 mg/l (4 µg/l)				
Boron			5 mg/l (5000 µg/l)	1.0 mg/l	1.0 mg/l	
Bromate	0	0.010 mg/l (10 µg/l)	0.01 mg/l 0.02 (10 µg/l)	10 µg/l	10 µg/l	
Bromodichloro-methane (BDCM)			0.016 mg/l (16 µg/l)	100 µg/l[5]		0.06 mg/l (60 µg/l)
Cadmium	0.005 mg/l (5 µg/l)	0.005 mg/l (5 µg/l)	0.005 mg/l (5 µg/l)	5.0 µg/l	5.0 µg/l	
Chlorate			1 mg/l (1000 µg/l)			
Chloride				250 mg/l	100 mg/l	
Clostridium perfringens				0 number/ 100 ml	0 number/ 100 ml	

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[5] Sum of concentrations of specified compounds: chloroform, bromoform, dibromochloromethane, bromodichloromethane

Pollutant	**United States**		**Canada**	**European Community**	**Czech Republic**	**World Health Organization**
	Maximum Contaminant Level Goal	**Maximum Contaminant Level**	**Maximum Acceptable Concentration**	**Parametric Value**	**Parametric Value**	**Guideline Value**
Conductivity				2 500 µS cm-1 at 20 C	2 500 µS cm-1 at 20 C	
Chlorite	0.8 mg/l (800 µg/l)	1.0 mg/l (1000 µg/l)	1 mg/l (1000 µg/l)		200 µg/l	
Chromium (total)	0.1 mg/l 0.2 (100 µg/l)	0.1 mg/l (100 µg/l)	0.05 mg/l (50 µg/l)	50 µg/l	50 µg/l	0.05 mg/l (50 µg/l)
Copper	1.3 mg/l	1.3 mg/l		2.0 mg/l	1,0 mg/l	2.0 mg/l
Cyanide (as free cyanide)	0.2 mg/l (200 µg/l)	0.2 mg/l (200 µg/l)	0.2 mg/l (200 µg/l)	50 µg/l	50 µg/l	
Cyanobacterial toxins -- microcystin-LR			0.0015 mg/l (1.5 µg/l)		1 µg/l	
1,2-dichloroethane				3.0 µg/l	3.0 µg/l	
Epichlorohydrin				0.10 µg/l	0.10 µg/	
Fluoride	4 mg/l	4 mg/l	1.5 mg/l	1.5 mg/l	1.5 mg/l	1.5 mg/l
Iron				200 µg/l	200 µg/l	
Lead	0	0.015 mg/l (15 µg/l)	0.01 mg/l (10 µg/l)	10 µg/l	10 µg/l	
Manganese				50 µg/l	50 µg/l	
Mercury (inorganic)	0.03 mg/l 0.04 (2 µg/l)	0.002 mg/l (2 µg/l)	0.01 mg/l (1 µg/l)	1.0 µg/l	1.0 µg/l	
Nickel				20 µg/l	20 µg/l	0.07 mg/l (70 µg/l)
Nitrate (measured as Nitrogen)	10 mg/l	10 mg/l	45 mg/l	50 mg/l	50 mg/l	50 mg/l
Nitrite (measured as Nitrogen)	1 mg/l	1 mg/l	3.2 mg/l	0.50 mg/l	0.50 mg/l	0.2 mg/l
Nickel				20 µg/l	20 µg/l	0.07 mg/l (70 µg/l)
Nitrate				50 mg/l	50 mg/l	
Nitrite				0.50 mg/l	0.50 mg/l	
Pesticides				0.10 µg/l	0.10 µg/l	
Pesticides - Total				0.50 µg/l	0.50 µg/l	
Polycyclic aromatic hydrocarbons				0.10 µg/l	0.10 µg/l	
Selenium	0.05 mg/l (50 µg/l)	0.05 mg/l (50 µg/l)	0.01 mg/l (10 µg/l)	10 µg/l	10 µg/l	0.01 mg/l (10 µg/l)

Pollutant	**United States**		**Canada**	**European Community**	**Czech Republic**	**World Health Organization**
	Maximum Contaminant Level Goal	**Maximum Contaminant Level**	**Maximum Acceptable Concentration**	**Parametric Value**	**Parametric Value**	**Guideline Value**
Sulfate				250 mg/l	250 mg/l	
Sodium				200 mg/l	200 mg/l	
Tetrachloroethene and Trichloroethene				10 µg/l	10 µg/l	0.07 mg/l (70 µg/l)
Thallium	0.0005 mg/l (0.5 µg/l)	0.002 mg/l (2 µg/l)				
Trihalomethanes (total)	N/A	0.080 mg/l (80 µg/l)		100 µg/l	100 µg/l	
Vinyl Chloride				0.50 µg/l	0.50 µg/l	
pH			6.5-8.5	6.5-9.5	6.5-9.5	

Sources: US Drinking Water Standards: http://www.epa.gov/ogwdw000/contaminants/index.html
WHO Guidelines for Drinking-Water Quality p.186, http://www.who.int/water_sanitation_health/dwq/fulltext.pdf

Table C- 3: Ambient air quality guidelines and standards

Pollutant	World Health Organization (WHO) Ambient Air Quality Guidelines		United States National Ambient Air Quality Standards				European Commission Air Quality Standards			Canada National Ambient Air Quality Objectives & Guidelines			
			Primary Standards		Secondary Standards								
	Averaging Period	Guideline Value (µg/m^3)	Averaging Period	Level	Averaging Period	Level	Averaging Period	Concentration	Permitted Exceedences Per Year	Averaging Time	Maximum Desirable Level	Maximum Acceptable Level	Maximum Tolerable Level
Sulfur Dioxide (SO_2)	24 hour	125 (interim target 1) 50 (interim target 2) 20 (guideline)	24 hour	0.14 ppm	3 hour	0.5 ppm	1 hour	350 µg/m^3	24	1 hour	172 ppb	334ppb	N/A
	10 minute	500 (guideline)	1 year	0.030 ppm			24 hour	125 µg/m^3	3	24 hour	57 ppb	115ppb	306ppb
										1 year	11 ppb	23ppb	N/A
Nitrogen Dioxide (NO2)	1 year	40 (guideline)	1 year	53 ppb (100 µg/m3)	1 year	0.053 ppm (100 µg/m^3)	1 year	200 µg/m^3	N/A	1 year	32 ppb	53ppb	N/A
	1 hour	200 (guideline)	1 hour	100 ppb	N/A	N/A	1 hour	40 µg/m^3	18	24?hour	N/A	106ppb	160ppb
										1?hour	N/A	213 ppb	532 ppb
Total Suspended Particulate (TSP)							1 year	N/A	120 µg/m^3	400 µg/m^3			
							24 hour	60 µg/m^3	70 µg/m^3	N/A			
Particulate Matter (PM10)	1 year	70 (interim target 1) 50 (interim target 2) 30 (interim target 3) 20 (guideline)	24 hour	150 µg/m^3	24 hour	150 µg/m^3	24 hour	50 µg/m^3	35				
	24 hour	150 (interim target 1) 100 (interim target 2) 75 (interim target 3) 50 (guideline)					1 year	40 µg/m^3	N/A				
Particulate Matter (PM2.5)	1?year	35 (interime target 1) 25 (interim target 2) 15 (interim target 3) 10 (guideline)	1?year	15.0 µg/m^3	1?year	15.0 µg/m^3	1?year	25 µg/m^3	N/A				
	24?hour	75 (interim target 1) 50 (interim target 2) 37.5 (interim target 3) 25 (guideline)	24?hour	35 µg/m^3	24?hour	35 µg/m^3							
Ozone	8hour	160 (interim target 1) 100 (guideline)	1 hour**	0.12 ppm (235 µg/m^3)	1 hour**	0.12 ppm (235 µg/m^3)	8 hour	120 µg/m^3	25 days averaged over 3 years	1 year	N/A	15 ppb	N/A
			8 hour	0.075 ppm	8 hour	0.075 ppm				24 hour	15 ppb	25ppb	N/A
										1 hour	51 ppb	82ppb	153ppb
Lead (Pb)	N/A	N/A	3 month	0.15 µg/m^3	3 month	0.15 µg/m^3	1 year	0.5 µg/m^3	N/A				
Carbon Monoxide (CO)	N/A	N/A	1 hour	35 ppm (40 mg/m^3)			8 hour	10 mg/m^3	N/A	1 hour	13 ppm	31 ppm	N/A
			8 hour	9 ppm (10 mg/m^3)						8 hour	5 ppm	13ppm	17 ppm
Benzene							1 year	5 µg/m^3	N/A				
Arsenic (As)							1 year	6 ng/m^3	N/A				
Cadmium (Cd)							1 year	5 ng/m^3	N/A				
Nickel (Ni)							1 year	20 ng/m^3	N/A				
Polycyclic Aromatic Hydrocarbons							1?year	1 ng/m^3 (expressed as a concentration of Benzo(a)pyrene)	N/A				

* Target value enters into force 1.1.2012

** The 1 hour U.S. Oxone standard was revoked beginning on June 15, 2005, and is being replaced by the 8 hour standard.

Sources: European Commission Air Quality Standards: http://ec.europa.eu/environment/air/quality/standards.htm
Canadian National Ambient Air Quality Objectives: http://www.hc-sc.gc.ca/ewh-semt/air/out-ext/reg-eng.php
WHO (quoted in International Finance Corporation Environmental, Health, and Safety General Guidelines):
http://www.ifc.org/ifcext/sustainability.nsf/AttachmentsByTitle/gui_EHSGuidelines2007_GeneralEHS/$FILE/Final+-+General+EHS+Guidelines.pdf
US National Ambient Air Quality Standards: http://epa.gov/air/criteria.htm

3 ENERGY-SECTOR SPECIFIC PERFORMANCE STANDARDS

Quantitative environmental performance standards may be applicable to all or some of the major types of projects designed to generate electricity: fossil fuel, hydroelectric and non-hydroelectric renewable energy. However, air emission limits, water discharge and effluent limits and waste standards developed by countries and international organizations tend to focus on fossil fuel fired steam electric power plants because they have the most significant potential and generalizable impacts through contamination of air and water resources.

Water discharge or effluent limits:

- Water discharges/effluent limits are summarized for fossil fuel powered, steam electric generating facilities.
- Hydroelectric dams may be subject to effluent limits that are calculated for a specific site taking into account changes in water flow and the need to control suspended solids for a particular waterway.
- Wastewater treatment standards and effluent limits also may apply to wastewater generated by employees working and/or living at the site.
- Specific water discharge limits have not been set on a national basis for other renewable energy sources.

Air emission limits:

- Emission limits are available and summarized for a range of sizes and types of fossil fuel powered electricity generating plants including, where available, those fueled either entirely or partially with renewable biofuels.
- Environmental impacts of specific hydropower facilities and other renewable energy sources should be considered on a case-by-case basis. The lack of emission limits for these other types of energy production does not mean that there are no impacts on air quality. For example, although once constructed hydroelectric dams would not generally be a significant source of air pollution, construction and transportation at such facilities may result in the release of pollutants into the air. For example, the building of dams to supply hydropower can result in the formation of lakes, which submerge vegetation growing along riverbanks. The decay of this vegetation can result in the release of methane, a greenhouse gas.

Waste:

- There are no broad based national and/or international performance standards provided for most electric generation waste, with the exception of coal ash.
- In general, fly ash waste, bottom ash waste, boiler slag waste, and flue gas emission control waste quantitative performance standards are currently under development.

Table C- 4: Environmental impacts from renewable energy sources

Renewable Energy Source	Environmental Impacts		
	Air	**Water**	**Waste Generation**
Solar	Negligible (no fuels combusted).	Solar technologies do not discharge any water while creating electricity.	Solar-thermal technologies do not produce any substantial amount of solid waste while creating electricity. The production of photovoltaic wafers creates very small amounts of hazardous materials.
Geothermal	Negligible (no fuels combusted).	Can possibly cause groundwater contamination when drilling wells and extracting hot water or steam. Re-injecting used water back into the ground prevents underground minerals from being introduced into surface waters.	Geothermal technologies do not produce a substantial amount of solid waste when generating electricity.
Biomass	Biomass power plants emit nitrogen oxides, particulate matter, carbon monoxide, carbon dioxide, and sulfur dioxide.	Biomass power plants have pollutant build-up in water used in the boiler and cooling system. The water used in cooling can also have an increased temperature upon discharge. Permits generally required.	The burning of biomass creates ash, though biomass ash generally has a low concentration of hazardous elements.
Wind	Negligible (no fuels combusted).	Wind turbines do not discharge any water while generating electricity.	Wind technologies do not produce any substantial amount of solid waste.

Source: USEPA website, non-hydroelectric renewable energy.
http://www.epa.gov/cleanenergy/energy-and-you/affect/non-hydro.html

3.1. Energy Sector Water Discharge / Effluent Limits

Table C- 5: Water discharge/effluent limits applicable to steam electric plants

Pollutant	Costa Rica	Dominican Republic	El Salvador	Nicaragua	United States	World Bank/IFC	Canada
	Effluent Limits for Energy Activities	Effluent Limits for Energy	Maximum Permitted Release to Water Body	Proposed Effluent Limits for Energy	For Steam Electric Generating Facilities	Maximum Effluent Values	Energy Effluent Regulations
Aluminum	5 mg/l		5 mg/l	2 mg/l	See section 3.2. for specifics.		
Arsenic	0.1 mg/l	0.1 mg/l	0.1 mg/l			0.5 mg/l	0.5 - 1 mg/l
Barium	5 mg/l		5 mg/l				
Boron	3 mg/l		1.5 mg/l				
Cadmium	0.1 mg/l	0.1 mg/l	0.1 mg/l	0.1 mg/l		0.1 mg/l	
Carbamates (total)	0.1 mg/l						
Chemical Oxygen Demand-COD		150 mg/l				150 mg/l	
Chlorine (residual)	1 mg/l						
Chromium-(total)	1.5 mg/l		1 mg/l	1 mg/l		0.5 mg/l	
Chromium (hexavalent)		0.1 mg/l	0.1 mg/l	0.5 mg/l		0.1 mg/l	
Color (purity)	15%		None				
Copper	0.5 mg/l	0.5 mg/l	1 mg/l	0.5 mg/l		0.5 mg/l	0.3 - 0.6 mg/l
Cyanide (total)	1 mg/l	1.0 mg/l	.5 mg/l	1 mg/l		1 mg/l	1 - 2 mg/l
Cyanide (free)	0.1 mg/l	0.1 mg/l				0.1 mg/l	
Cyanide (free but outside mixing area)	0.005 mg/l						
Cyanide (weak acid dissociable)	0.5 mg/l	0.5 mg/l				0.5 mg/l	
Fluoride	10 mg/l		5 mg/l				
Hydro-carbons	10 mg/l						
Iron		3.5 mg/l	10 mg/l (total)			1.0 mg/l	

Pollutant	Costa Rica	Dominican Republic	El Salvador	Nicaragua	United States	World Bank/IFC	Canada
	Effluent Limits for Energy Activities	Effluent Limits for Energy	Maximum Permitted Release to Water Body	Proposed Effluent Limits for Energy	For Steam Electric Generating Facilities	Maximum Effluent Values	Energy Effluent Regulations
Lead	0.5 mg/l	0.2 mg/l	0.4 mg/l	0.5 mg/l	See section 3.2. for specifics.	0.5 mg/l	0.2 - 0.4 mg/l
Mercury	0.01 mg/l	0.01 mg/l	0.01 mg/l			0.005 mg/l	
Nickel	1 mg/l	0.5 mg/l	0.2 mg/l	1 mg/l		0.5 mg/l	0.5 - 1.0 mg/l
Nitrogen (total)	50 mg/l		50 mg/l				
Oil and Grease		10 mg/l				10 mg/l	
Organo-phosphorus Compounds (total)	0.1 mg/l		0.1 mg/l				
Organo-chlorine Compounds (total)	0.05 mg/l		0.05 mg/l			0,2 mg/l	
Radium 226							0.37 - 1.11 Bq/l
Selenium	0.05 mg/l		0.05 mg/l				
Settleable Solids				1 ml/l			
Silver	1 mg/l		0.2 mg/l				
Sulfites	1 mg/l		?? 1000??				
Sulphides	25 mg/l						
Tin	2 mg/l						
Total Metals		10.0 mg/l				10 mg/l	
Total Suspended Solids (TSS)		50 mg/l		50 mg/l		50 mg/l	15 - 30 mg/l
Zinc	5 mg/l	2.0 mg/l	5 mg/l	1 mg/l		1.0 mg/l	0.5 - 1 mg/l
Temperature			20-35°C	40 °C			
pH		6.0-9.0	5.5-9.0	6.0-9.0		6.0-9.0	

3.1.1. *Water Discharges/Effluent Limits from Hydroelectric Dams*

Hydroelectric power plants generate electricity by passing running water through turbines. This water is released back into rivers after it has passed through the turbines, and the water is not polluted during this process.

However, the use of dams in hydropower generation can have other environmental impacts relating to water. For example, water in the lakes created by hydroelectric dams may be inhospitable to fish at greater depths because the water is too cold and oxygen-poor to support aquatic life. This cold, oxygen-poor water can be life-threatening to fish downstream. Further, the act of damming a river itself can have wide-ranging environmental impacts, from the presence of floods when the dam gates are opened to a disruption of normal water flows downstream.

3.2. Supplemental U.S. Water Discharge / Effluent Limits for the Energy Sector

Discharges of pollutants from any point source into the waters of the U.S. are prohibited except as in compliance with the Clean Water Act. 33 U.S.C. § 1311. Usually this means that for the discharges to be lawful they must be authorized by permit (The Clean Water Act section 301). Discharge permits are issued either by EPA or states with programs approved by EPA administering what is called the National Pollutant Discharge Elimination System (NPDES), or in the case of dredged or fill material the U.S. Army Corps of Engineers or a state authorized to administer a permit program for such discharges with EPA objection rights. 33 U.S.C. §§ 1342, 1344. NPDES permits must contain conditions that, at a minimum, meet water quality standards and technology-based effluent performance limits, which for the steam-electric power energy category, are found at 40 CFR 423. EPA takes into account both technological availability and economic achievability when it promulgates nationwide effluent limits, and the effluent standards are accessible via the EPA website (http://water.epa.gov/scitech/wastetech/guide/). The limits listed for reference here are current as of 2011. The EPA plans to update the regulations for the steam electric power generating industry in July 2012 and take final action by January 2014. The EPA website will include information on any updates.

Table C- 6: NPDES effluent limitations for steam electric generating facilities

Type of Waste Stream	Pollutant	NSPS Effluent Limitations	
		1-day Maximum	Maximum average of daily values for 30 consecutive days
Low-volume Waste Sources	Total Suspended Solids (TSS)	100.0 mg/l	30.0 mg/l
	Oil and grease	20.0 mg/l	15.0 mg/l
Chemical Metal Cleaning Wastes	TSS	100.0 mg/l	30.0 mg/l
	Oil and grease	20.0 mg/l	15.0 mg/l
	Copper, total	1.0 mg/l	1.0 mg/l
	Iron, total	1.0 mg/l	1.0 mg/l
Non-Chemical Metal Cleaning Wastes	Reserved	Reserved	Reserved
Bottom Ash Transport Water	TSS	100.0 mg/l	30.0 mg/l
	Oil and grease	20.0 mg/l	15.0 mg/l
Fly Ash Transport Water	No discharge	No discharge	No Discharge
Once-through Cooling Water (facilities with a generating capacity 25 MW or more)	Total Residual Chlorine	0.20 mg/l	0.20 mg/l
Once-through Cooling Water (facilities with a generating capacity of less than 25 MW)	Free Available Chlorine	0.5 mg/l	0.2 mg/l
Chemicals Used in Cooling Tower Blowdown	Free Available Chlorine	0.5 mg/l	0.2 mg/l
	Chromium, total	0.2 mg/l	0.2 mg/l
	Zinc, total	1.0 mg/l	1.0 mg/l
	Other priority pollutants	No discharge allowed	No discharge allowed
Coal Pile Runoff	TSS	50 mg/l	50 mg/l

Sources: 40 Code of Federal Regulations Part 423 §423.15 (2011).
http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&rgn=div5&view=text&node=40:28.0.1.1.23&idno=40#40:28.0.1.1.23.0.5.6
Sector Notebook Project: Fossil Fuel Electric Power Generation, p.111-112 (September 1997)
http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks

3.3. Air Emission Limits for the Energy Sector

Air emission limits are included from the International Finance Corporation Emission Guidelines and the U.S. Environmental Protection Agency.

3.3.1. International Finance Corporation (IFC) Emissions Guidelines

The International Finance Corporation's (IFC) Environmental, Health, and Safety (EHS) Guidelines offer both sector-specific and general requirements for projects and industries. IFC general emission guidelines apply to any facility or project that produces air emissions during any period of its lifecycle.

Table C- 7: IFC small combustion facilities emissions guidelines (3MWth-50MWth)

Combustion Technology/ Fuel	Particulate Matter (PM)	Sulfur Dioxide (SO_2)	Nitrogen Oxides (NO_x)	Dry Gas, Excess O_2 Content
Gas	N/A	N/A	200 (Spark Ignition) 400 (Dual Fuel) 1,600 Compression Ignition)	15%
Liquid	50 mg/Nm^3 (or up to 100 if justified by project specific considerations)	1.5% (or up to 3.0% if justified by project specific considerations)	1,460 mg/Nm^3 (Bore size diameter <400mm) 1,850 mg/Nm^3 (Bore size diameter > or =400mm)	15%
Turbine				
Natural Gas =3MWth to < 15MWth	N/A	N/A	42 ppm (Electric generation) 100 ppm (Mechanical drive)	15%
Natural Gas =15MWth to < 50MWth	N/A	N/A	25 ppm	15%
Fuels other than Natural Gas =3MWth to < 15MWth	N/A	0.5 % or lower (if commercially available without significant excess fuel cost)	96 ppm (Electric generation) 150 ppm (Mechanical drive)	15%
Fuels other than Natural Gas = 15MWth to < 50MWth	N/A	0.5% or lower (if commercially available without significant excess fuel cost)	74 ppm	15%
Boiler				
Gas	N/A	N/A	320 mg/Nm^3	3%
Liquid	50 mg/Nm^3 or up to 100 (if justified by environmental assessment)	2000 mg/Nm^3	460 mg/Nm^3	3%
Solid	50 or up to 100 (if justified by environmental assessment)	2000 mg/Nm^3	650 mg/Nm^3	6%

Source: IFC General EHS Guidelines p.7 (April 30, 2007).
http://www.ifc.org/ifcext/enviro.nsf/AttachmentsByTitle/gui_EHSGuidelines2007_GeneralEHS/$FILE/Final+-+General+EHS+Guidelines.pdf

Table C- 8: IFC emissions guidelines for boiler facilities

Combustion Technology/ Fuel	Pollutants (mg/Nm^3)						
	Particulate Matter (PM)		Sulfur Dioxide (SO_2)		Nitrogen Oxides (NO_x)		Dry Gas, Excess O2 Content (%)
	Non-Degraded Airshed (NDA)	Degraded Airshed (DA)	NDA	DA	NDA	DA	
Natural Gas	N/A	N/A	N/A	N/A	240	240	3%
Other Gaseous Fuels	50	30	400	400	240	240	3%
Liquid Fuels (50 MWh to 600 MWh)	50	30	900-1,500	400	400	200	3%
Liquid Fuels (More than 600 MWh)	50	30	200-850	200	400	200	3%
Solid Fuels (50 MWh to 600 MWh)	50	30	900-1,500	400	510	200	6%
Solid Fuels (More than 600 MWh)	50	30	200-850	200	510	200	6%

Source: IFC EHS Guidelines: THERMAL POWER PLANTS, p. 22. http://www.ifc.org/ifcext/sustainability.nsf/AttachmentsByTitle/gui_EHSGuidelines2007_ThermalPower/$File/FINAL_Thermal+Power.pdf

Table C- 9: IFC emissions guidelines for combustion turbines (units larger than 50 MWh)

Combustion Technology/ Fuel	Pollutants (mg/Nm^3)					
	Particulate Matter (PM)		Sulfur Dioxide (SO_2)		Nitrogen Oxides (NO_x)	Dry Gas, Excess O2 Content (%)
	Non-Degraded Airshed (NDA)	Degraded Airshed (DA)	NDA	DA	NDA/DA	
Natural Gas	N/A	N/A	N/A	N/A	51 (25 ppm)	15%
Fuels other than Natural Gas	50	30	Use of 1% or less S fuel	Use of 0.5% or less S fuel	152 (74 ppm)	15%

Source: IFC EHS Guidelines: THERMAL POWER PLANTS, p. 21. http://www.ifc.org/ifcext/sustainability.nsf/AttachmentsByTitle/gui_EHSGuidelines2007_ThermalPower/$File/FINAL_Thermal+Power.pdf

Table C- 10: IFC emissions guidelines for reciprocating engines

Combustion Technology/ Fuel	Pollutants (mg/Nm^3)						
	Particulate Matter (PM)		Sulfur Dioxide (SO_2)		Nitrogen Oxides (NO_x)		Dry Gas, Excess O2 Content
	Non-Degraded Airshed (NDA)	Degraded Airshed (DA)	NDA	DA	NDA	DA	
Natural Gas	N/A	N/A	N/A	N/A	200-400	200-400	15%
Liquid Fuels (More than 50 MWh and less than 300MWh)	50	30	1,170 or use of 2% or less S fuel	0.5% S	1,460-2,000	400	15%
Liquid Fuels (More than 300 MWh)	50	30	585 or use of 1% or less S fuel	0.2% S	740	400	15%
Biofuels/ Gaseous Fuels other than Natural Gas	50	30	N/A	N/A	30% above Natural Gas/Liquid Fuel Limits	200-400	15%

Source: IFC EHS Guidelines: THERMAL POWER PLANTS, p. 20.
http://www.ifc.org/ifcext/sustainability.nsf/AttachmentsByTitle/gui_EHSGuidelines2007_ThermalPower/$File/FINAL_Thermal+Power.pdf

3.3.2. *United States – New Source Performance Standards (NSPS) Applicable to Fossil Fuel Electric Power Generation*

Tables C-11 through C-22 summarize U.S. EPA's New Source Performance Standards for steam generating units combusting fossil fuels. The applicable standard for new construction varies based on the heat input and/or energy output of the unit, the fuel used, and the pollutant in question. All new facilities and existing facilities undergoing major modification or expansion must meet New Source Performance Standards, which are based on the use of the best available technology. Found at 40 CFR Part 60, the standards established for the fossil fuel electric power generation industry vary by facility size, type, and fuel. In recent years, the EPA has shifted to from input-based (lb/MMBtu), regulations to output-based (Ib/MWth) regulations. For more information on the benefits of output-based standards in air quality regulations, see http://www.epa.gov/chp/documents/obr_final_9105.pdf.

The performance standards are divided in the following size categories:

- Units generating > 73 MWth (250 MMBtu/hr) heat input of fossil fuels
- Units generating > 29 MWth (100 MMBtu/hr) and < 73 MWth
- Units generating ≥ 2.9 MWth (10 MMBtu/hr) and ≤ 29 MWth
- Stationary Gas Turbines

3.3.2.1. *Units with Heat Input > 73 MW (250 MMBtu/hr)*

Owners and operators that install, calibrate, maintain, and operate a continuous emissions monitoring system (CEMS) for measuring PM emissions are exempt from the opacity standard (§ 60.42Da(b)).

Opacity levels are to be based on a 6-minute average and may not exceed the maximum opacity except for one 6-minute period per hour in which the maximum opacity is 27%.

Table C- 11: Particulate matter (PM) emissions limits / reduction requirements

Compliance Alternatives		PM Emissions Limit		Percent Reduction of Potential Combustion Concentration	Maximum Opacity
		Gross Energy Output	Heat Input		
Alternative #1	Construction, Reconstruction, or Modification	18 ng/J (0.14 lb/MWh)	6.4 ng/J (0.015 lb/MMBtu)	—	20%
Alternative #2	Construction or Reconstruction	—	13 ng/J (0.03 lb/MMBtu)	And 99.90%	20%
	Modification	—	13 ng/J (0.03 lb/MMBtu)	And 99.80%	20%

Source: Code of Federal Regulations Title 40 Part 60 Section 60.42Da (Jan. 28, 2009).
http://edocket.access.gpo.gov/cfr_2009/julqtr/pdf/40cfr60.42Da.pdf

Table C- 12: Sulfur dioxide (SO2) emissions limits and reduction requirements

Facility Description / Fuel Type	SO_2 Emission Limit	Percent Reduction of Potential Combustion Concentration
New construction	180 ng/J (1.4 lb/MWh) Gross energy output	Or 95%
Reconstruction	180 ng/J (1.4 lb/MWh) Gross energy output OR 65 ng/J (0.15 lb/MMBtu) Heat input	Or 95%
Modification		Or 90%
Facilities that burn 75% or more (by heat input) coal refuse for:		
New Construction	180 ng/J (1.4 lb/MWh) Gross energy output	Or 94%
Reconstruction	180 ng/J (1.4 lb/MWh) Gross energy output OR 65 ng/J (0.15 lb/MMBtu) Heat input	Or 94%
Modification		Or 90%

Source: Code of Federal Regulations Title 40 Part 60 Section 60.43Da (June 13, 2007)
http://edocket.access.gpo.gov/cfr_2009/julqtr/pdf/40cfr60.44Da.pdf

When different fuels are combusted simultaneously, the applicable standard is determined by proration using the formulas that can be found at: Code of Federal Regulations Title 40 Part 60 Section 60.43Da (June 13, 2007). http://edocket.access.gpo.gov/cfr_2009/julqtr/pdf/40cfr60.43Da.pdf

Table C- 13: Oxides of nitrogen (NOX) emissions limits and reduction requirements

Facility Description / Fuel Type	Gross Energy Output	Heat Input
New construction	130 ng/J (1.0 lb/MWh)	-
Reconstruction	130 ng/J (1.0 lb/MWh)	47 ng/J (0.11 lb/MMBtu)
Modification	180 ng/J (1.4 lb/MWh)	65 ng/J (0.15 lb/MMBtu)

Source: Code of Federal Regulations Title 40 Part 60 Section 60.44Da (2011). http://ecfr.gpoaccess.gov/cgi/t/text/textidx?c=ecfr&sid=86668e4fac7c10a6a53edee0c19cb9c9&rgn=div8&view =text&node=40:6.0.1.1.1.10.158.5&idno=40

NOTES to "Oxides of Nitrogen (NO_x) Emissions Limits and Reduction Requirements" (40 CFR 60):

1 The owner or operator of an IGCC electric utility steam generating unit shall not cause to be discharged into the atmosphere any gases that contain NO_X(expressed as NO_2) in excess of 130 ng/J (1.0 lb/MWh) gross energy output on a 30-day rolling average basis. §60.44Da(f)

2 When burning liquid fuel exclusively or in combination with solid-derived fuel such that the liquid fuel contributes 50 percent or more of the total heat input to the combined cycle combustion turbine, the owner or operator shall not cause to be discharged into the atmosphere any gases that contain NO_X(expressed as NO_2) in excess of 190 ng/J (1.5 lb/MWh) gross energy output on a 30-day rolling average basis. §60.44Da(f)

3 In cases when during a 30-day rolling average compliance period liquid fuel is burned in such a manner to meet the conditions in paragraph (f)(2) of this section for only a portion of the clock hours in the 30-day period, the owner or operator shall not cause to be discharged into the atmosphere any gases that contain NO_X(expressed as NO_2) in excess of the computed weighted-average emissions limit based on the proportion of gross energy output (in MWh) generated during the compliance period for each of emissions limits in paragraphs (f)(1) and (2) of this section. §60.44Da(f)

EPA is currently developing air toxics standards for coal- and oil-fired electric generating units. For more information on the status of EPA proposals, visit http://www.epa.gov/ttn/atw/utility/utilitypg.html.

3.3.2.2. Units with Heat Input > 29 MW (100 MMBtu/hr) and < 73 MW

Units firing only very low sulfur oil, gaseous fuel, a mixture of these fuels, or a mixture of these fuels with any other fuels with a potential SO_2 emissions rate of 140 ng/J (0.23 lb/MMBtu) heat input or less are exempt from these SO_2 emissions limits. §60.42b(k)(2).

Table C- 14: Sulfur dioxide (SO2) emissions limits

Facility Description / Fuel Type	Option (where available)	SO_2 Emissions Limit	Percent Reduction of Potential Combustion Concentration
Facilities combusting coal, oil, natural gas, a mixture of these fuels, or a mixture of these fuels with any other fuels	Option #1	87 ng/J (0.20 lb/MMBtu) heat input	—
	Option #2	520 ng/J (1.2 lb/MMBtu) heat input	92%
Facilities located in noncontinental areas that combust coal	—	520 ng/J (1.2 lb/MMBtu) heat input	—
Facilities located in noncontinental areas that combust oil or natural gas	—	215 ng/J (0.50 lb/ MMBtu) heat input	—

Source: Code of Federal Regulations Title 40 Part 60 Section 60.42b (Jan. 28, 2009).
http://edocket.access.gpo.gov/cfr_2009/julqtr/pdf/40cfr60.42b.pdf

NOTE to "Sulfur Dioxide (SO_2) Emissions Limits (40 CFR 60)":

1 No owner or operator of an affected facility that combusts coal or oil, either alone or in combination with any other fuel, and that uses an emerging technology for the control of SO_2 emissions, shall cause to be discharged into the atmosphere any gases that contain SO_2 in excess of 50% of the potential SO_2 emission rate (50% reduction) and that contains SO_2 in excess of the emission limit determined according to the following formula:

$E_s = (K_c H_c + K_d H_d) / (H_c + H_d)$

Where: E_s = SO_2 emission limit, in ng/J or lb/MMBtu heat input

K_c = 260 ng/J (or 0.60 lb/MMBtu)

K_d = 170 ng/J (or 0.40 lb/MMBtu)

H_c = Heat input from the combustion of coal, in J (MMBtu)

H_d = Heat input from the combustion of oil, in J (MMBtu). §60.42(b).

Table C- 15: Particulate matter (PM) emissions limits

Facility Description / Fuel Type	PM Emissions Limit	Percent Reduction of Potential Combustion Concentration
Facilities that combust municipal-type solid waste and/or other fuels if the annual capacity factor for the other fuels is 10% or less	43 ng/J (0.10 lb/MMBtu) heat input	—
Facilities that combust coal, oil, wood, a mixture of these fuels, or a mixture of these fuels with any other fuels[4]	13 ng/J (0.030 lb/MMBtu) heat input	—
Facilities that combust coal, oil, wood, a mixture of these fuels, or a mixture of these fuels with any other fuels and for which modification commenced after Feb. 28, 2005	22 ng/J (0.051 lb/MMBtu) heat input	99.80%
Facilities that combust over 30% wood (by heat input) on an annual basis and have a maximum heat input capacity of 73 MW (250 MMBtu/h) or less, for which modification commenced after Feb. 28, 2005	43 ng/J (0.10 lb/MMBtu) heat input	—
Facilities that combust over 30% wood (by heat input) on an annual basis and have a maximum heat input capacity greater than 73 MW (250 MMBtu/h)	37 ng/J (0.085 lb/MMBtu) heat input	—

Source: Code of Federal Regulations Title 40 Part 60 Section 60.43b (Jan. 28, 2009). http://edocket.access.gpo.gov/cfr_2009/julqtr/pdf/40cfr60.43b.pdf

Table C- 16: Nitrogen oxide (NOX) emissions limits

Fuel / Steam Generating Unit Type		Nitrogen Oxide Emission Limits (Expressed as NO_x) Heat Input	
		ng/J	lb/MMBtu
(1) Natural gas and distillate oil, except (4)	(i) Low heat release rate	43	0.1
	(ii) High heat release rate	86	0.2
(2) Residual oil	(i) Low heat release rate	130	0.3
	(ii) High heat release rate	170	0.4
(3) Coal	(i) Mass-feed stoker	210	0.5
	(ii) Spreader stoker and fluidized bed combustion	260	0.6
	(iii) Pulverized coal	300	0.7
	(iv) Lignite, except (v)	260	0.6
	(v) Lignite mined in North Dakota, South Dakota, or Montana and combusted in a slag tap furnace	340	0.8
	(vi) Coal-derived synthetic fuels	210	0.5
(4) Duct burner used in a combined cycle system	(i) Natural gas and distillate oil	86	0.2
	(ii) Residual oil	170	0.4

Source: Code of Federal Regulations Title 40 Part 60 Section 60.44b (2011). http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=37145391a0a9f83eed8cdad550409621&rgn=div8&view=text&node=40:6.0.1.1.1.11.158.5&idno=40

NOTES to “Nitrogen Oxide (NO_x) Emissions Limits (40 CFR 60)”:

1 No owner or operator of an affected facility that simultaneously combusts coal, oil, or natural gas with a byproduct/waste shall cause to be discharged into the atmosphere any gases that contain NO_X in excess of the following formula unless the affected facility has an annual capacity factor for coal, oil, and natural gas of 10% or less and is subject to a federally enforceable requirement that limits operation of the affected facility to an annual capacity factor of 10% or less:

$E_n = [(EL_{go}H_{go}) + (EL_{ro}H_{ro}) + (EL_cH_c)] / (H_{go} + H_{ro} + H_c)$

Where:

E_n = NO_x emission limit (expressed as NO_2), ng/J (lb/MMBtu)
EL_{go} = Appropriate emission limit . . . for combustion of a natural gas or distillate oil, ng/J (lb/MMBtu)
H_{go} = Heat input from combustion of natural gas, distillate oil, and gaseous byproduct/waste, J (MMBtu)
EL_{ro} = Appropriate emission limit . . . for combustion of residual oil and/or byproduct/waste, ng/J (lb/MMBtu)
H_{ro} = Heat input from combustion of residual oil, J (MMBtu)
EL_c = Appropriate emission limit . . . for combustion of coal, ng/J (lb/MMBtu)
H_c = Heat input from combustion of coal, J (MMBtu). §60.44(b).

2 No owner or operator of an affected facility shall cause to be discharged into the atmosphere from that affected facility any gases that contain NO_X in excess of the following limits:

(1) If the affected facility combusts coal, oil, natural gas, a mixture of these fuels, or a mixture of these fuels with any other fuels: A limit of 86 ng/J (0.20 lb/MMBtu) heat input unless the affected facility has an annual capacity factor for coal, oil, and natural gas of 10 percent (0.10) or less and is subject to a federally enforceable requirement that limits operation of the facility to an annual capacity factor of 10 percent (0.10) or less for coal, oil, and natural gas; or

(2) If the affected facility has a low heat release rate and combusts natural gas or distillate oil in excess of 30 percent of the heat input on a 30-day rolling average from the combustion of all fuels, a limit determined by use of the following formula:

$$E_n = \frac{(0.10 \times H_{go}) + (0.20 \times H_r)}{(H_{go} + H_r)}$$

Where:
E_n= NO_X emission limit, (lb/MMBtu);
H_{go}= 30-day heat input from combustion of natural gas or distillate oil; and
H_r= 30-day heat input from combustion of any other fuel.

3 Units where more than 10 percent of total annual output is electrical or mechanical may comply with an optional limit of 270 ng/J (2.1 lb/MWh) gross energy output, based on a 30-day rolling average.

3.3.2.3. Units with Heat Input ≥ 2.9 MW (10 MMBtu/hr), ≤ 29 MW (100 MMBtu/hr)

Owners or operators of affected facilities that commence construction, reconstruction, or modification after Feb. 28, 2005 and that combust only oil that contains no more than 0.50 weight percent sulfur oil with other fuels not subject to a PM standard under §60.43c and not using a post-combustion technology (except a wet scrubber) to reduce PM or SO_2 emissions are not subject to the PM limit in this section. §60.43c(e)(4).

Table C- 17: Particulate matter (PM) emissions limits

Fuel Type / Facility Description	PM Emissions Limit	Percent Reduction of Potential Combustion Concentration
Facilities that combust coal, oil, wood, a mixture of these fuels, or a mixture of these fuels with other fuels and have a heat input capacity of 8.7 MW (30 MMBtu/hr) or greater	13 ng/J (0.03 lb/MMBtu) heat input	—
Facilities that combust coal, oil, wood, a mixture of these fuels, or a mixture of these fuels with other fuels and have a heat input capacity of 8.7 MW (30 MMBtu/hr) or greater and for which modification commenced after Feb. 28, 2005	22 ng/J (0.051 lb/MMBtu) heat input	99.80%
Facilities that combust over 30% wood (by heat input) on an annual basis and have a heat input capacity of 8.7 MW (30 MMBtu/hr) or greater and for which modification commenced after Feb. 28, 2005	43 ng/J (0.10 lb/MMBtu) heat input	—

Source: Code of Federal Regulations Title 40 Part 60 Section 60.43c (Jan. 28, 2009).
http://edocket.access.gpo.gov/cfr_2009/julqtr/pdf/40cfr60.43c.pdf

NOTE to "Particulate Matter (PM) Emissions Limits (40 CFR 60)":

1 Percent reduction requirements for SO_2 are not applicable to the following affected facilities: (1) affected facilities that have a heat input capacity of 22 MW (75 MMBtu/hr) or less; (2) affected facilities that have an annual capacity for coal of 55% or less and are subject to a federally enforceable requirement limiting operation of the affected facility to an annual capacity factor for coal of 55% or less; (3) affected facilities located in a noncontinental area; and (4) affected facilities that combust coal in a duct burner as part of a combined cycle system where 30% or less of the heat entering the steam generating unit is from combustion of coal in the duct burner and 70% or more of the heat entering the steam generating unit is from exhaust gases entering the duct burner. §60.42c(c)(1)-(4).

Table C- 18: Sulfur dioxide (SO2) emissions limits

Facility Description / Fuel Type	SO_2 Emissions Limit	Percent Reduction of Potential Combustion Concentration[6]
Facilities combusting only coal (must meet both standards)	87 ng/J (0.20 lb/MMBtu) heat input	—
	520 ng/J (1.2 lb/MMBtu) heat input	90%
Facilities combusting coal with other fuels	87 ng/J (0.20 lb/MMBtu) heat input	90%
Facilities combusting coal refuse alone in a fluidized bed combustion steam generating unit (must meet both standards)	87 ng/J (0.20 lb/MMBtu) heat input	—
	520 ng/J (1.2 lb/MMBtu) heat input	80%
Facilities combusting oil or other non-coal fuel with coal refuse	87 ng/J (0.20 lb/MMBtu) heat input	—
	See Equation	90%
Facilities combusting only coal and using emerging technology to control SO_2 emissions	260 ng/J (0.60 lb/MMBtu) heat input	50%
Facilities combusting coal with other fuels and using emerging technology to control SO_2 emissions	See Equation	50%
Facilities combusting oil	215 ng/J (0.50 lb/MMBtu) heat input[7]	—

Source: Code of Federal Regulations Title 40 Part 60 Section 60.42c (Jan. 28, 2009).
http://edocket.access.gpo.gov/cfr_2009/julqtr/pdf/40cfr60.42c.pdf

NOTES to "Sulfur Dioxide (SO_2) Emissions Limits (40 CFR Part 60)":

1 The owner or operator of an affected facility that:

(1) Combusts only coal refuse alone in a fluidized bed combustion steam generating unit shall neither:

(i) Cause to be discharged into the atmosphere from that affected facility any gases that contain SO_2in excess of 87 ng/J (0.20 lb/MMBtu) heat input or 20 percent (0.20) of the potential SO_2emission rate (80 percent reduction); nor

(ii) Cause to be discharged into the atmosphere from that affected facility any gases that contain SO_2in excess of SO_2in excess of 520 ng/J (1.2 lb/MMBtu) heat input.

(2) Combusts only coal and that uses an emerging technology for the control of SO_2emissions shall neither:

(i) Cause to be discharged into the atmosphere from that affected facility any gases that contain SO_2in excess of 50 percent (0.50) of the potential SO_2emission rate (50 percent reduction); nor

(ii) Cause to be discharged into the atmosphere from that affected facility any gases that contain SO_2in excess of 260 ng/J (0.60 lb/MMBtu) heat input.

2 As an alternative to meeting this requirement, an owner or operator of an affected facility may choose instead not to combust oil that contains greater than 0.5 weight percent sulfur. Percent reduction requirements do not apply to facilities combusting only oil. §60.42c(d).

3 The SO_2 emission limit for any affected facility that combusts coal, oil, or coal and oil with any other fuel is determined by the following formula:

$E_s = (K_aH_a + K_bH_b + K_cH_c) / (H_a + H_b + H_c)$

Where E_s = SO_2 emission limit, expressed in ng/J or lb/MMBtu heat input

K_a = 520 ng/J (1.2 lb/MMBtu)

K_b = 260 ng/J (0.60 lb/MMBtu)

K_c = 215 ng/J (0.50 lb/MMBtu)

H_a = Heat input from combustion of coal, except from facilities that combust coal and use an emerging technology to control SO_2 emissions, in J [MMBtu]

H_b = Heat input from combustion of coal in facilities that combust coal and use an emerging technology to control SO_2 emissions

H_c = Heat input from the combustion of oil, in J (MMBtu). §60.42c(e)(2).

3.3.2.4. Stationary Gas Turbines

The following standards are applicable to all stationary gas turbines with a heat input at peak load equal to or greater than 10.7 gigajoules (10 million Btu) per hour, based on the higher heating value of the fuel fired.

Table C- 19: NOX emissions limits for new stationary combustion turbines

Combustion Turbine Type	Combustion Turbine Heat Input at Peak Load (HHV)	NO_X Emission Standard
Natural Gas		
Electric generating	≤ 50 MMBtu/h	042 ppm at 15 percent O_2or 290 ng/J of useful output (2.3 lb/MWh).
Mechanical drive	≤ 50 MMBtu/h	100 ppm at 15 percent O_2or 690 ng/J of useful output (5.5 lb/MWh).
Firing natural gas	> 50 MMBtu/h and ≤ 850 MMBtu/h	25 ppm at 15 percent O_2or 150 ng/J of useful output (1.2 lb/MWh).
Firing natural gas	> 850 MMBtu/h	15 ppm at 15 percent O_2or 54 ng/J of useful output (0.43 lb/MWh)
Fuels Other Than Natural Gas		
Electric generating	≤ 50 MMBtu/h	96 ppm at 15 percent O_2or 700 ng/J of useful output (5.5 lb/MWh).
Mechanical drive	≤ 50 MMBtu/h	150 ppm at 15 percent O_2or 1,100 ng/J of useful output (8.7 lb/MWh).
Firing fuels other than natural gas	> 50 MMBtu/h and ≤ 850 MMBtu/h	74 ppm at 15 percent O_2or 460 ng/J of useful output (3.6 lb/MWh).
Firing fuels other than natural gas	> 850 MMBtu/h	42 ppm at 15 percent O_2or 160 ng/J of useful output (1.3 lb/MWh).
Heat Recovery Units		
Heat recovery units operating independent of the combustion turbine	All sizes	54 ppm at 15 percent O_2or 110 ng/J of useful output (0.86 lb/MWh).

Source: Code of Federal Regulations Title 40 Part 60 Section 60.4320 (2011).
http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr;sid=c13486c8995148442d6538ffd9563539;rgn=div6;view=text;node=40%3A6.0.1.1.1.101;idno=40;cc=ecfr

Owners or operators of stationary gas turbines have a choice of three options for meeting sulfur dioxide standards in continental areas and two options in non-continental areas, as shown in table C-21. The non-continental area standards also apply to continental areas where the EPA determines the area has no excess to natural gas and that the removal of sulfur compounds would cause more environmental harm than benefit.

Table C- 20: Sulfur dioxide (SO2) emissions limits by options

Continental Areas	
Option #1: Emissions-based Limit	Discharges into the atmosphere shall not contain SO_2 in excess of 110 nanograms per Joule (ng/J) (0.90 pounds per megawatt-hour (lb/MWh)) gross output.
Option #2: Fuel-based Limit	Fuel burned in a stationary gas turbine shall not contain total potential sulfur emissions in excess of 26 ng SO_2/J (0.060 lb SO_2/MMBtu) heat input.
Option #3: Biogas Option	For each stationary combustion turbine burning at least 50 percent biogas on a calendar month basis, as determined based on total heat input, discharges into the atmosphere shall not contain SO_2 in excess of 65 ng SO_2/J (0.15 lb SO_2/MMBtu) heat input.
Non Continental Areas	
Option #1: Emissions-based Limit	Discharges into the atmosphere shall not contain SO_2in excess of 780 ng/J (6.2 lb/MWh) gross output,
Option #2: Fuel-based Limit	Fuel burned in a stationary gas turbine shall not contain total potential sulfur emissions in excess of 180 ng SO_2/J (0.42 lb SO_2/MMBtu) heat input. If your turbine simultaneously fires multiple fuels, each fuel must meet this requirement.

Source: Code of Federal Regulations Title 40 Part 60 Section 60.43330 (2011).
http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=f11117950ffbc58cd1c9345904b23117&rgn=div8&view=text&node=40:6.0.1.1.1.101.280.7&idno=40

4 INTERNATIONAL TREATIES AND AGREEMENTS

CAFTA-DR countries have ratified and/or signed a number of international treaties and agreements which provide commitments to adopting and implementing a range of environmental protection regimes. Most do not confer specific quantitative benchmarks for performance and so are not summarized in this Appendix. However, for convenience they are listed below as of the date of publication.

Table C- 21: Multilateral environmental agreements ratified (R) or signed (S) by CAFTA-DR countries

Multilateral Environmental Agreement	Costa Rica	Dominican Republic	El Salvador	Guatemala	Honduras	Nicaragua
Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal **entered into force** - 5 May 1992	R	R	R	R	R	R
Convention on **Biological Diversity** - abbreviated as Biodiversity **entered into force** - 29 December 1993	R	R	R	R	R	R
Convention on **Wetlands** of International Importance Especially as **Waterfowl Habitat** (Ramsar) **entered into force** - 21 December 1975	R	R	R	R	R	R
Convention on the International Trade in **Endangered Species** of Wild Flora and Fauna (CITES) **entered into force** - 1 July 1975	R	R	R	R	R	R
Convention on the Prevention of **Marine Pollution by Dumping Wastes** and Other Matter (London Convention) **entered into force** - 30 August 1975	R	R		R	R	
Convention on the **Prohibition of Military or Any Other Hostile Use** of Environmental Modification Techniques **entered into force** - 5 October 1978	R			R		R
United Nations Framework Convention on **Climate Change entered into force -** 21 March 1994	R	R	R	R	R	R
Kyoto Protocol to the United Nations Framework Convention on **Climate Change entered into force** - 23 February 2005	R	R	R	R	R	R
Montreal Protocol on **Substances That Deplete the Ozone Layer entered into force** – 1 January 1989	R	R	R	R	R	R
International Convention for the Regulation of **Whaling entered into force** - 10 November 1948	R			R		R
International **Tropical Timber** Agreement, 1994 **entered into force** - 1 January 1997				R	R	
Protocol of 1978 Relating to the International Convention for the Prevention of **Pollution From Ships**, 1973 (MARPOL) **entered into force** - 2 October 1983		R		R	R	R
United Nations Convention on the **Law of the Sea** (LOS) **entered into force** - 16 November 1994	R	S	S	R	R	R
United Nations Convention to Combat **Desertification** in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa **entered into force** - 26 December 1996	R	R	R	R	R	R

Source: https://www.cia.gov/library/publications/the-world-factbook/appendix/appendix-c.html

5 ENERGY SECTOR WEBSITE REFERENCES

More information on environmental impacts, mitigation measures, industry best practices, and quantitative standards for the energy sector can be found at the following websites:

INTERNATIONAL FINANCE ORGANIZATION (www.ifc.org)

Environmental, Health, and Safety Guidelines
English: www.ifc.org/ifcext/sustainability.nsf/Content/EHSGuidelines
Español: http://www.ifc.org/ifcext/sustainability.nsf/Content/EHSGuidelines_Spanish

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (www.epa.gov)

Regulatory Information for the Energy Sector
English: www.epa.gov/lawsregs/bizsector/energy.html

Power Generator Compliance Assistance
English: www.epa.gov/compliance/assistance/sectors/power.html

Profile of the Fossil Fuel Electric Power Generation Industry
English:
http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/fossil.html

Non-Hydroelectric Renewable Energy
English: www.epa.gov/cleanenergy/energy-and-you/affect/non-hydro.html

Hydroelectricity
English: www.epa.gov/cleanenergy/energy-and-you/affect/hydro.html

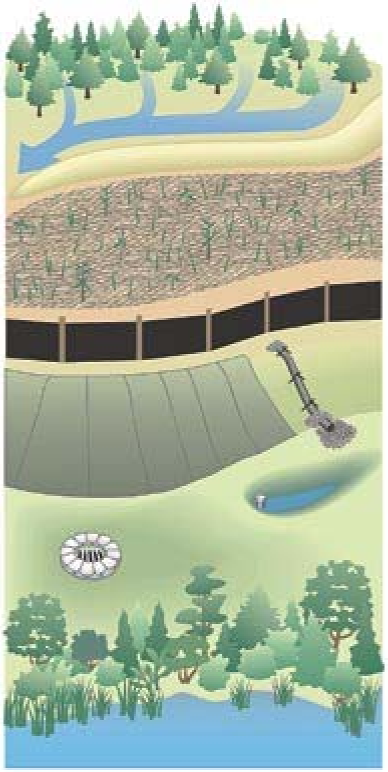
APPENDIX D. RULES OF THUMB FOR EROSION AND SEDIMENTATION CONTROL

RULES OF THUMB FOR EROSION AND SEDIMENT CONTROL
(Excerpted from Kentucky Erosion Prevention and Sediment Control Field Guide)

TETRA TECH funded by
Kentucky Division of Water (KDOW), Nonpoint Source Section
and the Kentucky Division of Conservation (KDOC) through a grant from USEPA

http://www.epa.gov/region8/water/stormwater/pdf/Kentucky%20Erosion%20prevention%20field%20guide.pdf

This Appendix presents illustrations and photographs of Best Management Practices for Erosion and Sediment Control. This information was excerpted from the US EPA funded Kentucky Erosion Prevention and Sediment Control Field Guide.



BASIC RULES

Preserve existing Vegetation

Divert upland runoff around exposed soil

Seed/mulch/ cover bare soil immediately

Use sediment barriers to trap soil in runoff

Protect slopes and channels from gullying

Install sediment traps and settling basins

Preserve vegetation near all waterways

NEED FOR EROSION AND SEDIMENT CONTROL MEASURES

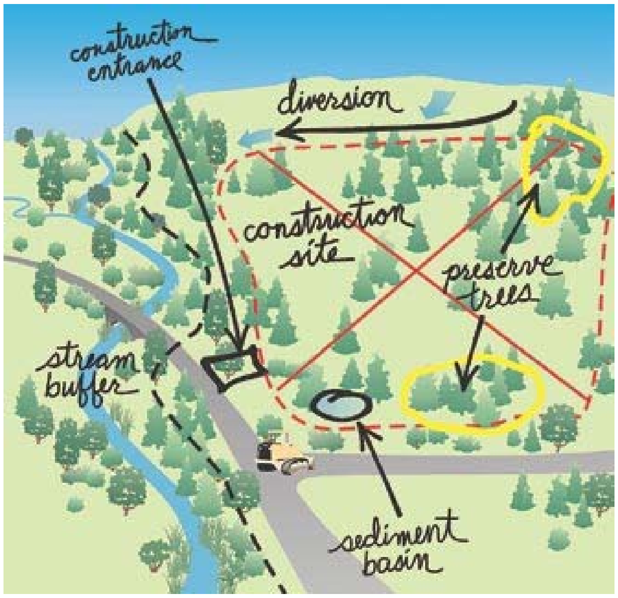
	Soil Type		
Slope Angle	**Silty**	**Clays**	**Sandy**
Very Steep (2:1 or more)	*Very high*	*High*	*High*
Steep (2:1–4:1)	*Very High*	*High*	*Moderate*
Moderate (5:1–10:1)	*High*	*Moderate*	*Moderate*
Slight (10:1–20:1	*Moderate*	*Moderate*	*Low*

PRIORIZATION OF EROSION AND SEDIMENT CONTROL MEASURES

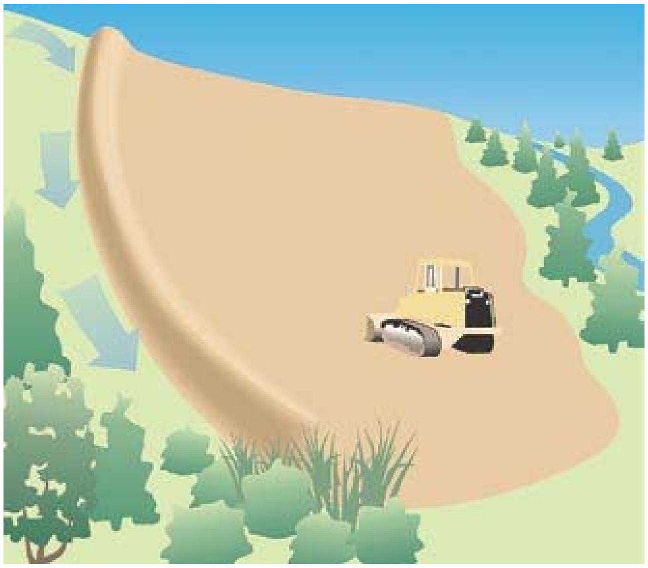
PRACTICE	COST	EFFECTIVENESS
Limiting disturbed area through phasing	**$**	*****
Protecting disturbed areas with mulch and revegetation	**$$**	****
Installing diversions around disturbed areas	**$$$**	***
Sediment removal through detention of all site drainage	**$$$$**	**
Other structural controls to contain sediment laden drainage	**$$$$$**	*

PLAN AHEAD

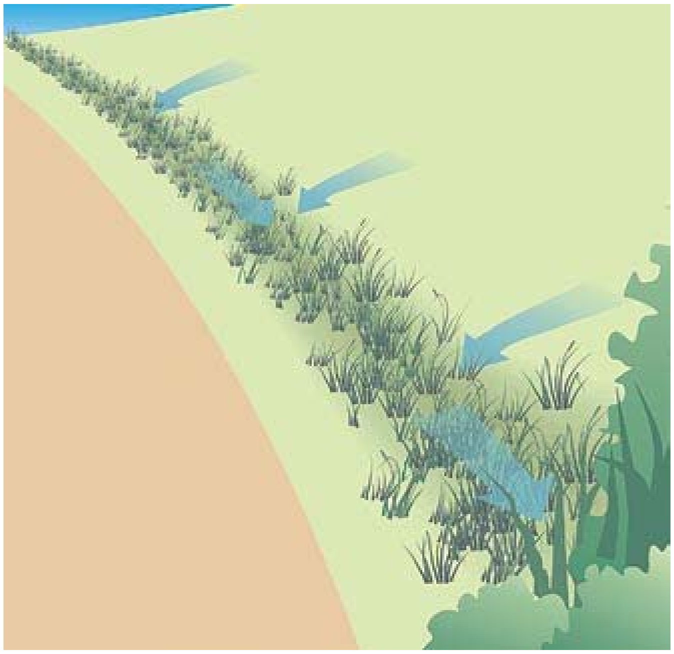
Identify drainage areas and plan for drainage ditches and channels, diversions, grassed channels, sediment traps/basins, down slope sediment barriers, and rock construction and install before beginning excavation.



DIVERT RUNOFF AROUND EXCAVATION AND DISTURBANCE



Berms and ditches diverting clean upland runoff around construction sites reduce erosion and sedimentation problems. Seed berms and ditches after construction.

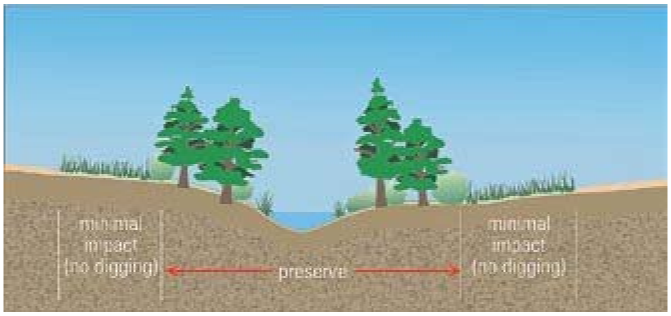


Diversion ditches should be lined with grass at a minimum, and blankets if slopes exceed 10:1

VEGETATIVE BUFFERS

Vegetated buffers above or below your work site are always a plus.

They trap sediment before it can wash into waterways, and prevent bank erosion.



Vegetated waterways help move upland water through or past your site while keeping it clear of mud. Do not disturb existing vegetation along banks, and leave a buffer of tall grass and shrubs between stream bank trees and disturbed areas.

Good construction, seeding, and stabilization of diversion berm. Note that diversion ditch is lined with grass on flatter part of slope, and with rock on steeper part.

SOIL COVER VS EROSION PROTECTION

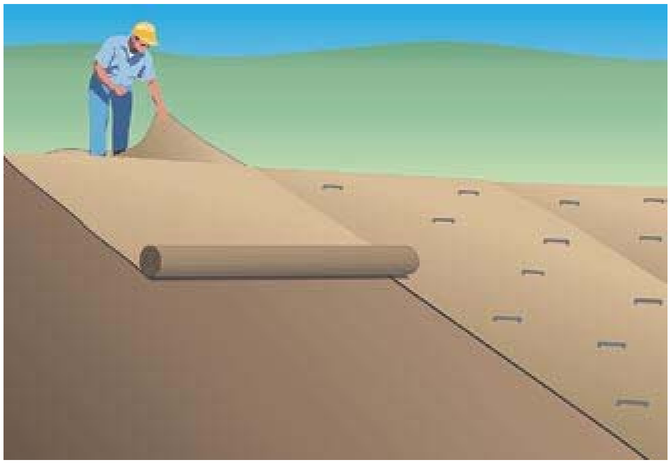
SOIL COVERING	EROSION REDUCTION
Mulch (hay or straw)	
1.2 ton per 0.4 hectare	75 percent
1 ton per 0.4 hectare	87 percent
2 tons per 0.4 hectare	98 percent
Grass (seed or sod)	
40 percent cover	90 percent
60 percent cover	96 percent
90 percent cover	99 percent
Bushes and shrubs	
25 percent cover	60 percent
75 percent cover	72 percent
Trees	
25 percent cover	58 percent
75 percent cover	64 percent
Erosion control blankets	95–99 percent

Prepare bare soil for planting by disking across slopes, scarifying, or tilling if soil has been sealed or crusted over by rain. Seedbed must be dry with loose soil to a depth of 3 to 6 inches.

For slopes steeper than 4:1, walk bulldozer or other tracked vehicle up and down slopes before seeding to create tread-track depressions for catching and holding seed. Mulch slopes after seeding if possible. Cover seed with erosion control blankets or turf mats if slopes are 2:1 or greater. Apply more seed to ditches and berms.

Erosion and sediment loss is virtually eliminated on seeded areas (left side). Rills and small gullies form quickly on unseeded slopes (right).

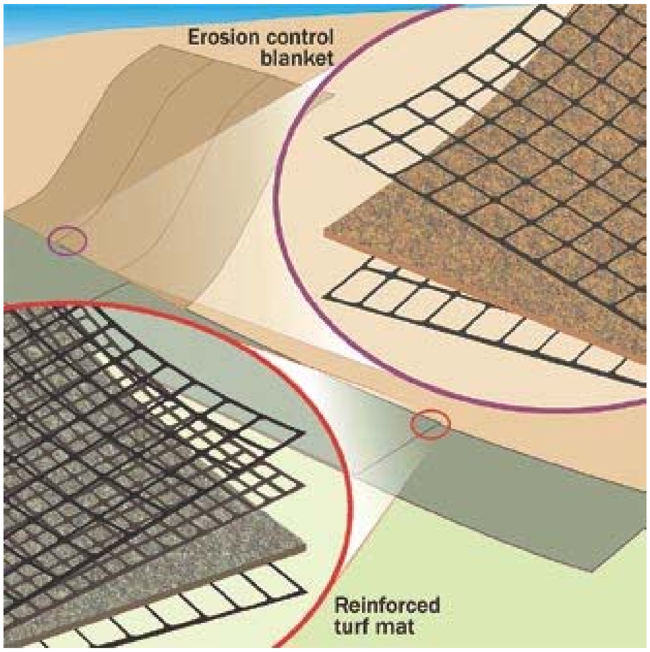
BLANKET INSTALLATION (GEOFABRIC)



Install blankets and mats vertically on long slopes. Unroll from top of hill, staple as you unroll it. Do not stretch blankets.

Erosion control blankets are thinner and usually degrade quicker than turf reinforced mats. Check manufacturer's product information for degradation rate (life span), slope limitations, and installation.

Remember to apply seed, fertilizer, and lime before covering with blankets or mats!

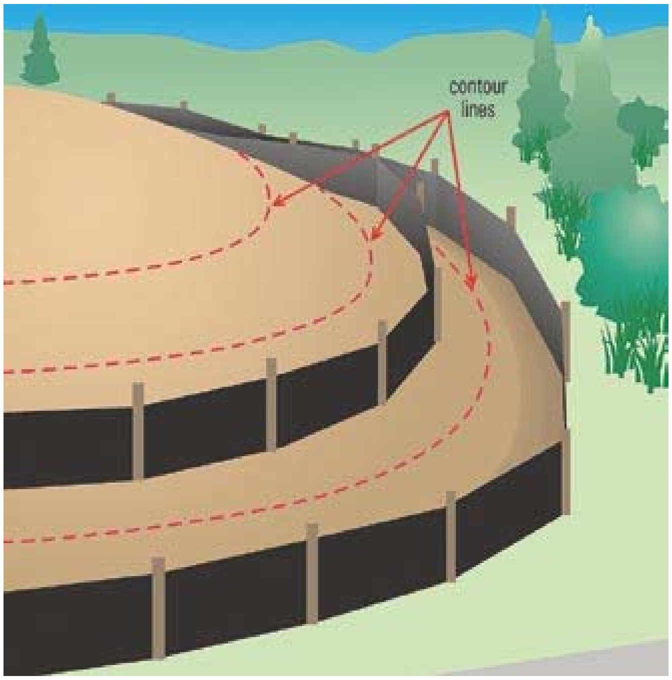


Blankets installed along stream banks or other short slopes can be laid horizontally. Install blankets vertically on longer slopes. Ensure 15 cm minimum overlap.

BLANKET INSTALLATION

SITE CONDITIONS	BLANKET INSTALLATION NOTES
Ditches and channels (from high flow line to ditch bottom)	• Grade, disk, and prepare seedbed. • Seed, lime, and fertilize the area first • Install horizontally (across slope). • Start at ditch bottom. • Staple down blanket center line first. • Staple & bury top in 8" deep trench. • Top staples should be 12" apart. • Uphill layers overlap bottom layers. • Side overlap should be 6"–8". • Side & middle staples = 24" apart. • Staple below the flow level every 12". • Staple thru both blankets at overlaps.
Long slopes, including areas above ditch flow levels	• Grade, disk, and prepare seedbed. • Seed, lime, and fertilize first. • Install vertically (up & down hill). • Unroll from top of hill if possible. • Staple down center line of blanket first. • Staple & bury top in 8" deep trench. • Top staples should be 12" apart. • Side & middle staples = 24" apart. • Uphill layers overlap downhill layers. • Overlaps should be 6"–8". • Staple thru both blankets at overlap.

SEDIMENT BARRIERS (Silt fences and others)

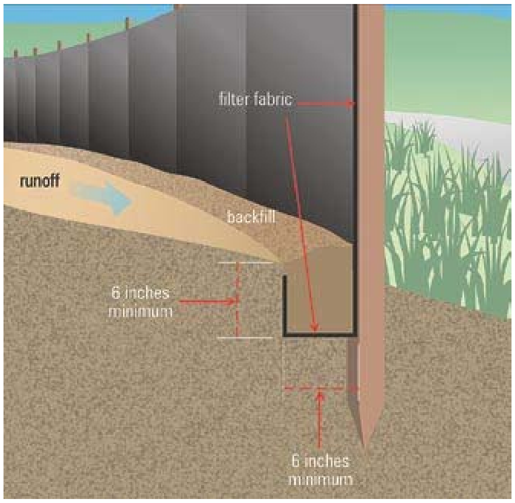


Silt fences should be installed on the contour below bare soil areas.

Use multiple fences on long slopes 20 to 26 meters a part. Remove accumulated sediment before it reaches halfway up the fence.

Each 33-meter section of silt fence can filter runoff from about 0.6 hectare (about 35 meters uphill). To install a silt fence correctly, follow these steps:

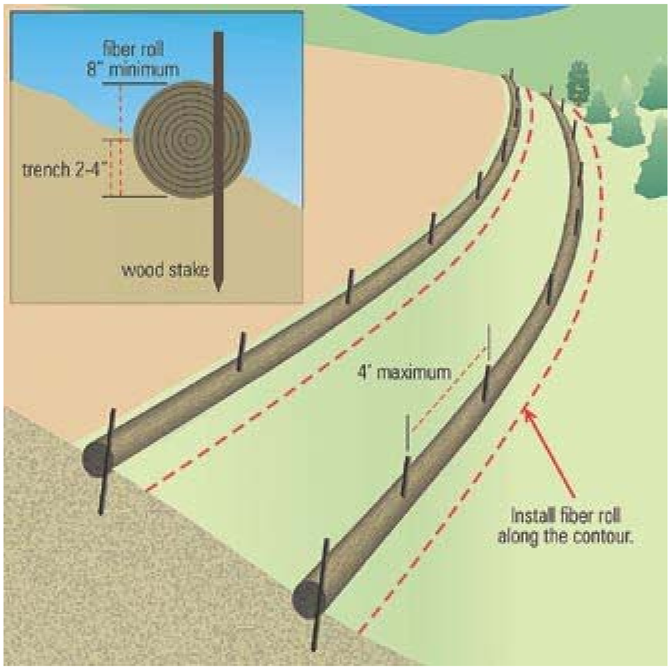
- Note the location & extent of the bare soil area
- Mark silt fence location just below bare soil area
- Make sure fence will catch all flows from area
- Dig trench 15 centimeters deep across slope



- Unroll silt fence along trench.
- Join fencing by rolling the end stakes together.
- Make sure stakes are on downhill side of fence.
- Drive stakes in against downhill side of trench.
- Drive stakes until 20 to 25 centimeters of fabric is in trench.
- Push fabric into trench; spread along bottom.
- Fill trench with soil and tamp down.

Stakes go on the downhill side. Dig trench first, install fence in downhill side of trench, and tuck fabric into trench, then backfill on the uphill side (the side toward the bare soil area).

Use J-hooks to trap and pond muddy runoff flowing along uphill side of silt fence. Turn ends of silt fence toward the uphill side to prevent bypassing. Use multiple J-hooks every 17 to 50 meters for heavier flows.



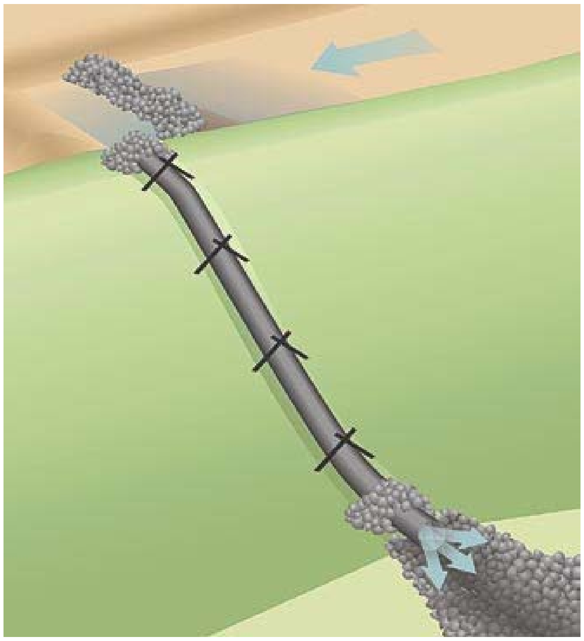
Fiber rolls can be used to break up runoff flows on long slopes. Install on the contour and trench in slightly. Press rolls firmly into trench and stake down securely. Consult manufacturer's instructions for expected lifespan of product, slope limits, etc. As always, seed and mulch long slopes as soon as possible.

Very good installation of multiple silt fences on long slope. Turn ends of fencing uphill to prevent bypass. Leave silt fences up until grass is well established on all areas of the slope. Re-seed bare areas as soon as possible. Remove or spread accumulated sediment and remove silt fence after all grass is up.

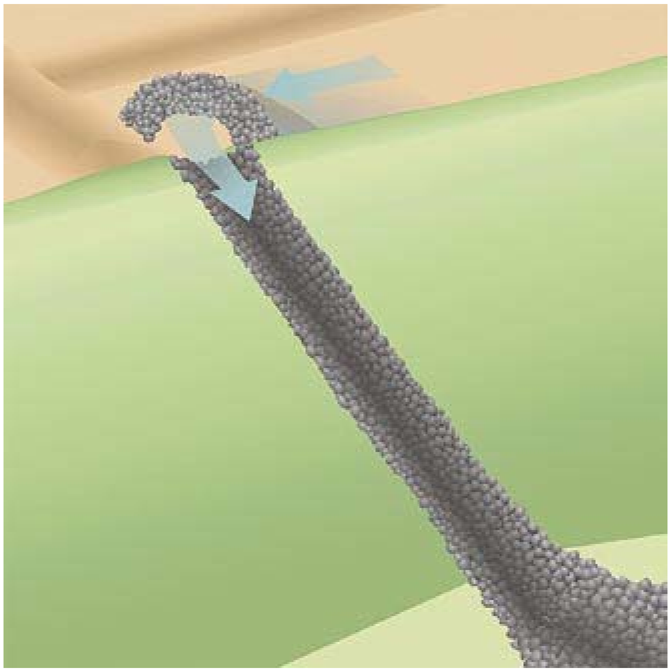
SLOPE PROTECTION TO PREVENT GULLIES

If soil is:	Erosion will be:
Compacted and smooth	30 percent *more*
Tracks across slopes	20 percent *more*
Tracks up & down slopes	10 percent *less*
Rough and irregular	10 percent *less*
Rough & loose to 12" deep	20 percent *less*

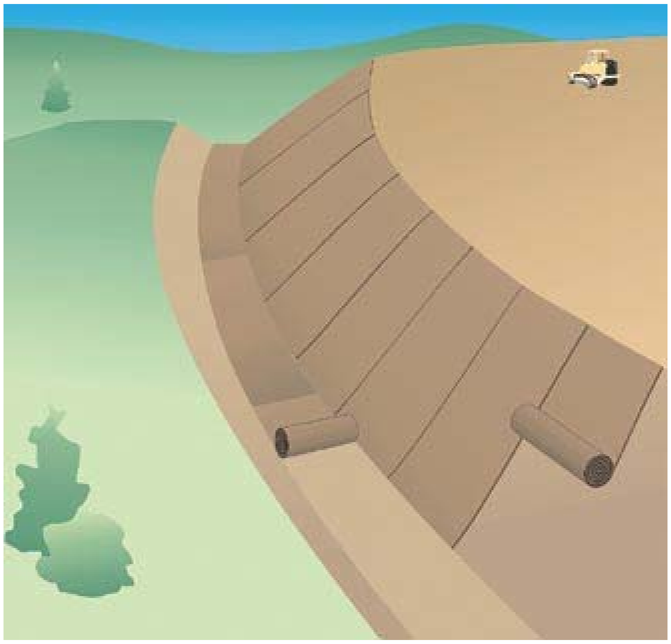
Tread-track slopes up and down hill to improve stability.



Temporary down drain using plastic pipe. Stake down securely, and install where heavy flows need to be transported down highly erodible slopes. Note silt check dam in front of inlet.



Temporary or permanent down drain using geotextile underliner and riprap. All slope drains must have flow dissipaters at the outlet to absorb high energy discharges, and silt checks at the inlet until grass is established.



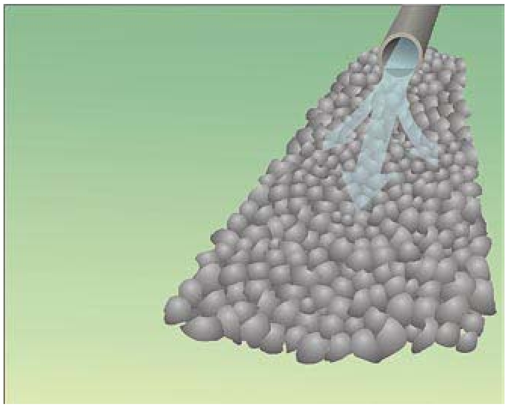
Steep, long slopes need blankets or mats. Install blankets and mats up and down long slopes. For channels below slopes, install horizontally. Don't forget to apply seed, lime, and fertilizer (if used) before installing blanket.

Other methods that could be considered are breaking up steep slopes with terraces, ditches along contours, straw bales and other methods.

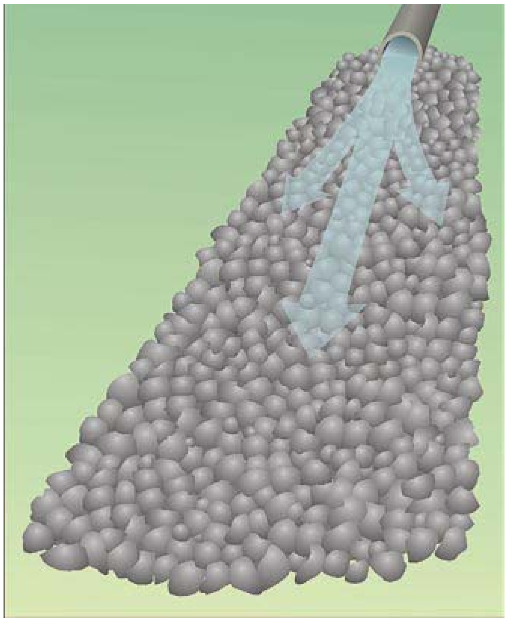
PROTECTING DITCHS AND CULVERTS INLETS/OUTLETS

Very good application of mixed rock for culvert inlet ponding dam. Mixing rock promotes better ponding, drainage, and settling of sediment.

Excellent placement and construction of rock apron to dissipate flows from culvert outlet. Area needs seeding and mulching.



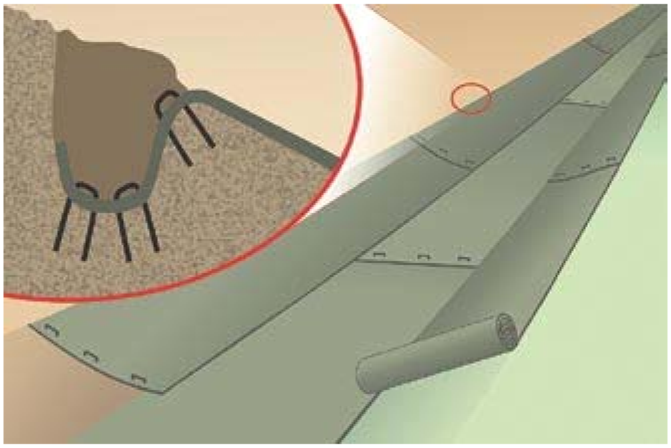
Low-flow energy dissipaters (above) are shorter than those for high-flow outlets (below).



STABILIZING DRAINAGE DITCHES

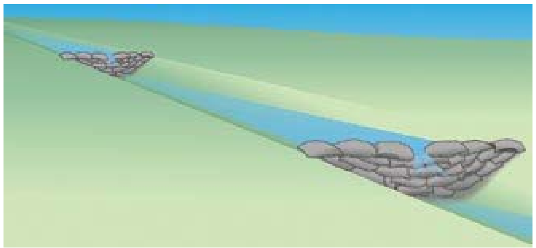
Stabilization approaches for drainage ditches

	Soil Type in Ditch		
Ditch Slope	**Sandy**	**Silty**	**Clays**
Steep >10%	Concrete or riprap	Concrete or riprap	Riprap
Moderate 10%	Riprap with filter fabric	Riprap or turf mats &seeding	Riprap or turf mats& seeding
Slight 5%	Riprap or turf mats &seeding	Seeding &turf mats	Seeding &turf mats
Mostly Flat <3%	Seeding &blankets	Seeding &mulching	Seeding &mulching



Lay in ditch blankets similar to roof shingles; start at the lowest part of the ditch, then work your way up. Uphill pieces lap over downhill sections. Staple through both layers around edges. Trench, tuck, and tamp down ends at the top of the slope. Do not stretch blankets or mats.

Check Dams



Silt check dams of rock, stone-filled bags, or commercial products must be installed before uphill excavation or fill activities begin. See table below for correct silt check spacing for various channel slopes. Tied end of bag goes on downstream side.

Spacing of Check Dams in Ditches

Ditch Slope	Check Dam Spacing (meters)	Additional Information
30%	*3.2*	*Calculated for 1 meter high check dam*
20%	*5*	
15%	*7*	
10%	*12*	*Center of the dam should be 150 centimeters lower than the sides*
5%	*17*	
3%	*33*	
2%	*50*	*Use 15 to 25 cm rock, stone bags, or commercial products*
1%	*100*	
0.5%	*200*	

Good installation of temporary rock silt checks. Remember to tie sides of silt check to upper banks. Middle section should be lower. Clean out sediment as it accumulates. Remove silt checks after site and channel are stabilized with vegetation.

Good placement and spacing of fiber-roll silt checks. Coconut fiber rolls and other commercial products can be used where ditch slopes do not exceed three percent.

DITCH LINING

Ditch lined with rock.

Rock Sizing for ditch liners

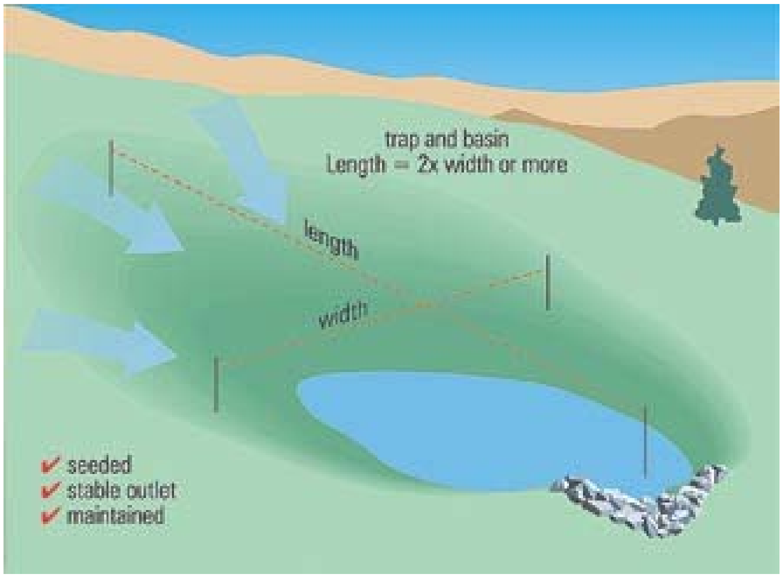
Flow Velocity	Average rock diameter
2 m/sec	12.5 cm
2.5 m/sec	25.0 cm
3.3 m/sec	35.0 cm
4 m/sec	50.0 cm

SEDIMENT TRAPS AND BASINS

In general, sediment traps are designed to treat runoff from about 1 to 5 acres. Sediment basins are larger, and serve areas of about 5 to 10 acres. Basins draining areas larger than 10 acres require an engineered design, and often function as permanent storm water treatment ponds after construction is complete.

Sediment traps

Any depression, swale, or low-lying place that receives muddy flows from exposed soil areas can serve as a sediment trap. Installing several small traps at strategic locations is often better than building one large basin. The simplest approach is to dig a hole or build a dike (berm) of earth or stone where concentrated flows are present. This will help to detain runoff so sediment can settle out. The outlet can be a rock lined depression in the containment berm.



Sediment basins

Sediment basins are somewhat larger than traps, but the construction approach is the same. Sediment basins usually have more spillway protection due to their larger flows. Most have risers and outlet pipes rather than rock spillways to handle the larger flows. Sediment basins are often designed to serve later as storm water treatment ponds. If this is the case, agreements are required for long-term sediment removal and general maintenance. Construction of a permanent, stable outlet is key to long-term performance.

Sizing and design considerations

A minimum storage volume of 130 cubic meters per 0.4 hectare of exposed soil drained is required for basins and traps. Traps and basins are designed so that flow paths through the trap or basin are as long as possible, to promote greater settling of soil particles. Sediment basin length must be twice the width or more if possible—the longer the flow path through the basin, the better.

Side slopes for the excavation or earthen containment berms are 2:1 or flatter. Berms are made of well-compacted clayey soil, with a height of 1.5 meters or less. Well mixed rock can also be used as a containment berm for traps. Place soil fill for the berm or dam in 15 cm layers and compact. The entire trap or basin, including the ponding area, berms, outlet, and discharge area, must be seeded and mulched immediately after construction. An overflow outlet can be made by making a notch in the containment berm and lining it with rock. Rock in the notch must be large enough to handle over-flows, and the downhill outlet should be stabilized with rock or other flow dissipaters similar to a culvert outlet. Overflow should be at an elevation so dam will not overtop. Allow at least 0.33 meter of freeboard. Outlets must be designed to promote sheet flow of discharges onto vegetated areas if possible. If the discharge will enter a ditch or channel, make sure it is stabilized with vegetation or lined.

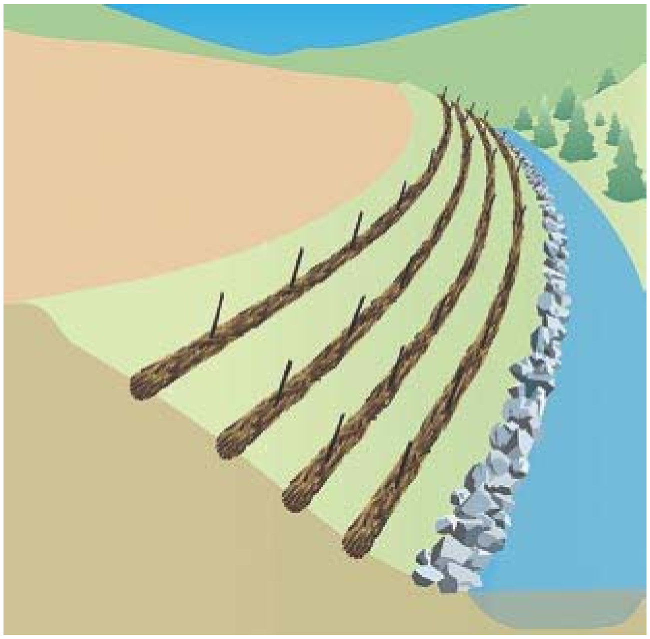
PROTECTING STREAMS AND STREAM BANKS

Recommended Setbacks of Activities from Streams

	Soil Type Along Banks		
Bank Slope	**Sandy**	**Silty**	**Clays**
Very Steep (2:1 or more)	33 m	27 m	20 m
Steep (4:1 or more)	27 m	20 m	13 m
Moderate (6:1 or more)	20 m	13 m	10 m
Mostly flat (< 10:1)	13 m	10 m	6.5 m

Vegetated buffers

Preserve existing vegetation near waterways wherever possible. This vegetation is the last chance barrier to capture sediment runoff before it enters the lake, river, stream, or wetland. Where vegetation has been removed or where it is absent, plant native species of trees, shrubs, and grasses.



Live hardwood stakes driven through live wattles or rolls and trenched into slope provide excellent stream bank protection. Protect toe of slope with rock or additional rolls or rocks.

STREAM CROSSINGS

Keep equipment away from and out of streams. If a temporary crossing is needed, put it where the least stream or bank damage will occur. Look for:

- Hard stream bottom areas
- Low or gently sloping banks
- Heavy, stable vegetation on both sides

Use one or more culverts, as needed, sized to carry the two-year 24-hour rain storm. Cover culverts with at least 27 cm of soil and at least 15 cm inches of mixed rock. An 8.5 meter long, 15 cm thick pad of rock should extend down the haul road on each side of the crossing.

Good use of silt fence, straw, rock and other practices for temporary stream crossing. Any work in stream channels—such as installation of culverts

APPENDIX E. SAMPLING AND ANALYSIS PLAN

GUIDANCE AND TEMPLATE

VERSION 2, PRIVATE ANALYTICAL SERVICES USED
R9QA/002.1
April, 2000

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 9

This Sampling and Analysis Plan (SAP) guidance and template is based on USEPA guidance as presented at http://ndep.nv.gov/BCA/file/reid_sap.pdf. It is intended assist organization in documenting the procedural and analytical requirements for baseline and routine monitoring of surface water ground water, soils, and biological samples. It has originally developed to characterize contaminated land but has been modified here to address sampling, laboratory analysis, and quality control/quality assurance for evaluation pre-mining, mining, and post mining hydrologic and biologic conditions. This guide is to be used as a template. It provides item-by-item instructions for creating a SAP and includes example language which can be used with or without modification.

1 INTRODUCTION

[This section should include a brief description of the project, including the history, problem to be investigated, scope of sampling effort, and types of analyses that will be required. These topics will be covered in depth later so do not include a detailed discussion here.]

1.1. Site Name or Sampling Area

[Provide the most commonly used name of the site or sampling area.]

1.2. Site or Sampling Area Location

[Provide a general description of the region, or district in which the site or sampling area is located. Detailed sampling location information should be provided later in Section 2.]

1.3. Responsible Organization

[Provide a description of the organization conducting the sampling.]

1.4. Project Organization

[Provide the name and phone number(s) of the person(s) and/or contractor working on the sampling project as listed in the table. The table can be modified to include titles or positions appropriate to the specific project. Delete personnel or titles not appropriate to the project.]

Title/Responsibility	**Name**	**Phone Number**
Project Manager		
Staff		
Quality Assurance Manager		
Contractor (Company Name)		

Contractor Staff

1.5. Statement of the Specific Problem

[In describing the problem, include historical, as well as recent, information and data that may be relevant. List and briefly outline citizens' complaints, public agency inspections, and existing data. Include sources of information if possible.]

2 BACKGROUND

This section provides an overview of the location of, previous investigations of, and the apparent problem(s) associated with the site or sampling area. [Provide a brief description of the site or sampling area, including chemicals used on the site, site history, past and present operations or activities that may have contributed to the suspected contamination, etc.]

2.1. Site or Sampling Area Description [Fill in the blanks.]

[Two maps of the area should be provided: the first (Figure 2.1), on a larger scale, should place the area within its geographic region; the second (Figure 2.2), on a smaller scale, should mark the sampling site or sampling areas within the local area. Additional maps may be provided, as necessary, for clarity. Maps should include a North arrow, groundwater flow arrow (if appropriate), buildings or former buildings, project area, area to be disturbed, etc. If longitude or latitude information is available, such as from a Global Positioning System (GPS), provide it. Sampling locations can be shown in Figure 2.2.]. Example language is as follows:

The site or sampling area occupies __________ [e.g., hectares or square meters] in a ________________ [e.g., urban, commercial, industrial, residential, agricultural, or undeveloped] area. The site or sampling area is bordered on the north by ___________, on the west by ______________, on the south by ________________, and on the east by ________________. The specific location of the site or sampling area is shown in Figure 2.2.

____
____
____
____
____

The second paragraph (or set of paragraphs) should describe historic and current on-site structures and should be consistent with what is presented in Figure 2.2.

2.2. Operational History

[As applicable, describe in as much detail possible (i.e., use several paragraphs) the past and present activities at the site or sampling area. The discussion might include the following information:

- **A description of the owner(s) and/or operator(s) of the site or areas near the site, the watershed of interest, the sampling area, etc. (present this information chronologically);**
- **A description of past and current operations or activities that may have contributed to suspected contamination of the sit;**
- **A description of the processes involved in the operation(s) and the environmentally detrimental substances, if any, used in the processes;**
- **A description of any past and present waste management practices.**
- **If a waste site, were/are hazardous wastes generated by one or more of the processes described earlier? If so, what were/are they, how and where were/are they stored on the site**

or sampling area, and where were/are they ultimately disposed of? If an ecosystem, what point and non-point sources which may have affected the river, stream, lake or watershed?]

2.3. Previous Investigations/Regulatory Involvement

[If applicable] [Summarize all previous sampling efforts at the site or sampling area. Include the sampling date(s); name of the party(ies) that conducted the sampling; local, regional, or federal government agency for which the sampling was conducted; a rationale for the sampling; the type of media sampled (e.g., soil, sediment, water); laboratory methods that were used; and a discussion of what is known about data quality and usability. The summaries should be presented in subsections according to the media that were sampled (e.g., soil, water, etc.) and chronologically within each medium. Attach reports or summary tables of results or include in appendices if necessary.]

2.4. Geological Information

[Groundwater sampling only][Provide a description of the hydrogeology of the area. Indicate the direction of groundwater flow, if known.]

2.5. Environmental and/or Human Impact

[Discuss what is known about the possible and actual impacts of the possible environmental problem on human health or the environment.]

3 PROJECT DATA QUALITY OBJECTIVES

Data Quality Objectives (DQOs) are qualitative and quantitative statements for establishing criteria for data quality and for developing data collection designs.

3.1. Project Task and Problem Definition

[Describe the purpose of the environmental investigation in qualitative terms and how the data will be used. Generally, this discussion will be brief and generic. Include all measurements to be made on an analyte specific basis in whatever medium (soil, sediment, water, etc.) is to be sampled. This discussion should relate to how this sampling effort will support the specific decisions described in Section 3.2.]

3.2. Data Quality Objectives (DQOs)

Data quality objectives (DQOs) are quantitative and qualitative criteria that establish the level of uncertainty associated with a set of data. This section should describe decisions to be made based on the data and provide criteria on which these decisions will be made.

[Discuss Data Quality Objectives, action levels, and decisions to be made based on the data here.]

3.3. Data Quality Indicators (DQIs)

Data quality indicators (accuracy, precision, completeness, representativeness, comparability, and method detection limits) refer to quality control criteria established for various aspects of data gathering, sampling, or analysis activity. In defining DQIs specifically for the project, the level of uncertainty associated with each measurement is defined. Definition of the different terms are provided below:

- *Accuracy is the degree of agreement of a measurement with a known or true value. To determine accuracy, a laboratory or field value is compared to a known or true concentration.*

Accuracy is determined by such QC indicators as: matrix spikes, surrogate spikes, laboratory control samples (blind spikes) and performance samples.

- *Precision is the degree of mutual agreement between or among independent measurements of a similar property (usually reported as a standard deviation [SD] or relative percent difference [RPD]). This indicator relates to the analysis of duplicate laboratory or field samples. An RPD of <20% for water and <35% for soil, depending upon the chemical being analyzed, is generally acceptable. Typically field precision is assessed by co-located samples, field duplicates, or field splits and laboratory precision is assessed using laboratory duplicates, matrix spike duplicates, or laboratory control sample duplicates).*
- *Completeness is expressed as percent of valid usable data actually obtained compared to the amount that was expected. Due to a variety of circumstances, sometimes either not all samples scheduled to be collected can be collected or else the data from samples cannot be used (for example, samples lost, bottles broken, instrument failures, laboratory mistakes, etc.). The minimum percent of completed analyses defined in this section depends on how much information is needed for decision making. Generally, completeness goals rise the fewer the number of samples taken per event or the more critical the data are for decision making. Goals in the 75-95% range are typical.*
- *Representativeness is the expression of the degree to which data accurately and precisely represent a characteristic of an environmental condition or a population. It relates both to the area of interest and to the method of taking the individual sample. The idea of representativeness should be incorporated into discussions of sampling design. Representativeness is best assured by a comprehensive statistical sampling design, but it is recognized that is usually outside the scope of most one-time events. Most one time SAPs should focus on issues related to judgmental sampling and why certain areas are included or not included and the steps being taken to avoid either false positives or false negatives.*
- *Comparability expresses the confidence with which one data set can be compared to another. The use of methods from EPA or "Standard Methods" or from some other recognized sources allows the data to be compared facilitating evaluation of trends or changes in a site, a river, groundwater, etc. Comparability also refers to the reporting of data in comparable units so direct comparisons are simplified (e.g., this avoids comparison of mg/L for nitrate reported as nitrogen to mg/L of nitrate reported as nitrate, or ppm vs. mg/L discussions).*
- *Detection Limit(s) (usually expressed as method detection limits for all analytes or compounds of interest for all analyses requested must be included in this section. These limits should be related to any decisions that will be made as a result of the data collection effort. A critical element to be addressed is how these limits relate to any regulatory or action levels that may apply.*

DQI tables are available from the QA Office for most routinely ordered methods. These tables can be attached to the SAP and referenced in this section. If an organization, its contractor, or its laboratory wish to use different limits or acceptance criteria, the table should be modified accordingly. SOPs should be included for methods not covered by the DQI tables or they can be submitted in lieu of the tables. Due to resource constraints, generally only the DQI aspects of these SOPs will be evaluated.

[Provide or reference DQI tables here.]

3.4. Data Review and Validation

This section should discuss data review, including what organizations or individuals will be responsible for what aspects of data review and what the review will include.

[Discuss data review and data validation here including what organizations or individuals will be responsible for what aspects of data review and what the review will include. This section should also discuss how data that do not meet data quality objectives will be designated, flagged, or otherwise handled. Possible corrective actions associated with the rejection of data, such as reanalysis, resampling, no action but monitor the data more closely next quarter, etc., also need to be addressed.]

3.5. Data Management

[Provide a list of the steps that will be taken to ensure that data are transferred accurately from collection to analysis to reporting. Discuss the measures that will be taken to review the data collection processes, including field notes or field data sheets; to obtain and review complete laboratory reports; and to review the data entry system, including its use in reports. A checklist is acceptable.]

3.6. Assessment Oversight

[Describe the procedures which will be used to implement the QA Program. This would include oversight by the Quality Assurance Manager or the person assigned QA responsibilities. Indicate how often a QA review of the different aspects of the project, including audits of field and laboratory procedures, use of performance samples, review of laboratory and field data, etc., will take place. Describe what authority the QA Manager or designated QA person has to ensure that identified field and analytical problems will be corrected and the mechanism by which this will be accomplished.]

4 SAMPLING RATIONALE

For each sampling event, the SAP must describe the sampling locations, the media to be sampled, and the analytes of concern at each location. A rationale should then be provided justifying these choices. The following sections are subdivided on a media specific basis among soil, sediment, water, and biological media. Other media should be added as needed. This section is crucial to plan approval and should be closely related to previously discussed DQOs.

4.1. Soil Sampling

[Provide a general overview of the soil sampling event. Present a rationale for choosing each sampling location at the site or sampling area and the depths at which the samples are to be taken, if relevant. If decisions will be made in the field, provide details concerning the criteria that will be used to make these decisions (i.e., the decision tree to be followed). List the analytes of concern at each location and provide a rationale for why the specific chemical or group of chemicals (e.g., trace metals etc.) were chosen. Include sampling locations in Figure 2.2 or equivalent.]

4.2. Sediment Sampling

[Provide a general overview of the sediment sampling event. Present a rationale for choosing each sampling location at the site or sampling area and the depths or area of the river, stream or lake at which the samples are to be taken, if relevant. If decisions will be made in the field, provide details concerning the criteria that will be used to make these decisions (i.e., the decision tree to be followed). List the analytes of concern at each location and provide a rationale for why the specific chemical or group of chemicals (e.g., trace metals) were chosen. Include sampling locations in Figure 2.2 or equivalent.]

4.3. Water Sampling

[Provide a general overview of the water sampling event. For groundwater, describe the wells to be sampled or how the samples will be collected (e.g., hydro punch), including the depths at which the samples are to be taken. For surface water, describe the depth and nature of the samples to be collected (fast or slow moving water, stream traverse, etc.). Present a rationale for choosing each sampling location or sampling area. If decisions will be made in the field, provide details concerning the criteria that will be used to make these decisions (i.e., the decision tree to be followed). List the analytes of concern at each location and provide a rationale for why the specific chemical or group of chemicals (e.g., trace metals) were chosen. For microbiological samples, discuss the types of bacterial samples being collected. Include sampling locations in Figure 2.2 or equivalent.]

4.4. Biological Sampling

[For each of the two types of events identified, provide a general overview of the biological sampling event. Present a rationale for choosing each sampling location at the site or sampling area, including the parameters of interest at each location. If decisions will be made in the field, provide details concerning the criteria that will be used to make these decisions (i.e., the decision tree to be followed).

4.4.1. *Biological Samples for Chemical Analysis*

[For sampling where flora or fauna will be analyzed for the presence of a chemical (e.g. fish collected for tissue analysis), explain why the specific chemical or group of chemicals (e.g., metals, organochlorine pesticides, etc.) is included. List the types of samples to be collected (e.g., fish, by species or size, etc.) and explain how these will be representative. Include sampling locations in Figure 2.2 or equivalent.]

4.4.2. *Biological Sample for Species Identification and Habitat Assessment*

[If the purpose of the sampling is to collect insects or other invertebrates or to make a habitat assessment, a rationale for the sampling to take place should be provided. For example: what species are of interest and why?]

5 REQUEST FOR ANALYSES

This section should discuss analytical support for the project depending on several factors including the analyses requested, areas of concern, turnaround times, available resources, available laboratories, etc. If samples will be sent to more than one organization it should be clear which samples go to which laboratory. Field analyses for pH, conductivity, turbidity, or other field tests should be discussed in the sampling section. Field measurements in a mobile laboratory should be discussed here and differentiated from samples to be sent to a fixed laboratory. Field screening tests (for example, immunoassay tests) should be discussed in the sampling section, but the confirmation tests should be discussed here and the totals included in the tables.

[Complete the following narrative subsection concerning the analyses for each matrix. In addition, fill in Tables 5-1 through 5-5, as appropriate. Each table must be completed to list analytical parameters for each type of sample. Include information on container types, sample volumes, preservatives, special handling and analytical holding times for each parameter. Quality Control (QC) samples (blanks, duplicates, splits, and laboratory QC samples, see Section 10 for description) should be indicated in the column titled "Special Designation." The extra volume needed for laboratory QC samples (for water samples only) should be noted on the table. The tables provided do not have to be

used, but the critical information concerning the number of samples, matrix, analyses requested and QC sample identification should be provided in some form. The selected analyses must be consistent with earlier discussion concerning DQOs and analytes of concern. DQI information for the methods should be discussed in Section 8 on quality control requirements.]

5.1. Analyses Narrative

[Fill in the blanks. Provide information for each analysis requested. Delete the information below as appropriate. Include any special requests, such as fast turn-around time (2 weeks or less), specific QC requirements, or modified sample preparation techniques in this section.]

5.2. Analytical Laboratory

[A QA Plan from the laboratory or SOPs for the methods to be performed must accompany the SAP.]

6 FIELD METHODS AND PROCEDURES

In the general introductory paragraph to this section, there should be a description of the methods and procedures that will be used to accomplish the sampling goals, e.g., "...collect soil, sediment and water samples." It should be noted that personnel involved in sampling must wear clean, disposable gloves of the appropriate type. The sampling discussion should track the samples identified in Section 4.0 and Table(s) 5-1, 5-2, 5-3, or 5-4. A general statement should be made that refers to the sections containing information about sample tracking and shipping (Section 7). Provide a description of sampling procedures. Example procedures are provided below, but the organization's own procedures can be used instead. In that case, attach a copy of the applicable SOP.

6.1. Field Equipment

6.1.1. *List of Equipment Needed*

[List all the equipment that will be used in the field to collect samples, including decontamination equipment, if required. Discuss the availability of back-up equipment and spare parts.]

6.1.2. *Calibration of Field Equipment*

[Describe the procedures by which field equipment is prepared for sampling, including calibration standards used, frequency of calibration and maintenance routines. Indicate where the equipment maintenance and calibration record(s) for the project will be kept.]

6.2. Field Screening

In some projects a combination of field screening using a less accurate or sensitive method may be used in conjunction with confirmation samples analyzed in a fixed laboratory. This section should describe these methods or reference attached SOPs. Analyses such as soil gas or immunoassay kits are two examples.

[Describe any field screening methods to be used on the project here including how samples will be collected, prepared, and analyzed in the field. Include in an appendix, as appropriate, SOPs covering these methods. Confirmation of screening results should also be described. The role of the field screening in decision making for the site should also be discussed here if it has not been covered previously.]

6.3. Soil

6.3.1 *Surface Soil Sampling*

[Use this subsection to describe the collection of surface soil samples that are to be collected within 15-30 centimeters of the ground surface. Specify the method (e.g., hand trowels) that will be used to collect the samples and use the language below or reference the appropriate sections of a Soil Sampling SOP.]

[If exact soil sampling locations will be determined in the field, this should be stated. The criteria that will be used to determine sampling locations, such as accessibility, visible signs of potential contamination (e.g., stained soils, location of former fuel storage tank, etc.), and topographical features which may indicate the location of hazardous substance disposal (e.g., depressions that may indicate a historic excavation) should be provided.]

Exact soil sampling locations will be determined in the field based on accessibility, visible signs of potential contamination (e.g., stained soils), and topographical features which may indicate location of hazardous substance disposal (e.g., depressions that may indicate a historic excavation). Soil sample locations will be recorded in the field logbook as sampling is completed. A sketch of the sample location will be entered into the logbook and any physical reference points will be labeled. If possible, distances to the reference points will be given.

[If surface soil samples are to be analyzed for organic (non volatile compounds and other analytes, use this paragraph; otherwise delete.]

Surface soil samples will be collected as grab samples (independent, discrete samples) from a depth of 0 to ___centimeters below ground surface (bgs). Surface soil samples will be collected using a stainless steel hand trowel. Samples to be analyzed for volatile organic compounds will be collected first (see below). Samples to be analyzed for __________ [List all analytical methods for soil samples except for volatile organic compounds] will be placed in a sample-dedicated disposable pail and homogenized with a trowel. Material in the pail will be transferred with a trowel from the pail to the appropriate sample containers. Sample containers will be filled to the top, taking care to prevent soil from remaining in the lid threads prior to being closed to prevent potential contaminant migration to or from the sample. Sample containers will be closed as soon as they are filled, chilled to 4°C if appropriate, and processed for shipment to the laboratory.

[If surface soil samples are to be analyzed for volatile organic compounds (VOCs), use this paragraph; otherwise delete.]

Surface soil samples for VOC analyses will be collected as grab samples (independent, discrete samples) from a depth of 0 to ___ [centimeters or meters] below ground surface (bgs). Surface soil samples will be collected using a 5 gram Encore sampling device, and will be collected in triplicate. Samples will be sealed using the Encore sampler and a zip lock bag or else transferred directly from the sampler into a VOA vial containing either 10 mLs of methanol or sodium bisulfate solution. Sample containers will be closed as soon as they are filled, chilled immediately to 4°C before wrapping them in bubble wrap, and processed them for shipment to the laboratory.

[For surface soil samples which are not to be analyzed for volatile compounds, use this paragraph; otherwise delete.]

Surface soil samples will be collected as grab samples (independent, discrete samples) from a depth of 0 to ___ [centimeters or meters] below ground surface (bgs). Surface soil samples will be collected using a stainless steel hand trowel. Samples will be placed in a sample-dedicated disposable pail and homogenized with a trowel. Material in the pail will be transferred with a trowel from the pail to the appropriate sample containers. Sample containers will be filled to the top, taking care to prevent soil from remaining in the lid threads prior to being closed to prevent potential contaminant migration to or from the sample. Sample containers will be closed as soon as they are filled, chilled if appropriate, and processed for shipment to the laboratory.

6.3.2 *Subsurface Soil Sampling*

[Use this subsection for subsurface soil samples that are to be collected 30 cm or more below the surface. Specify the method (e.g., hand augers) that will be used to access the appropriate depth and then state the depth at which samples will be collected and the method to be used to collect and then transfer samples to the appropriate containers or reference the appropriate sections of a Soil Sampling SOP. If SOPs are referenced, they should be included in an Appendix.]

[If exact soil sampling locations will be determined in the field, this should be stated. The criteria that will be used to determine sampling locations, such as accessibility, visible signs of potential contamination (e.g., stained soils), and topographical features which may indicate the location of hazardous substance disposal (e.g., depressions that may indicate a historic excavation) should be provided. There should also be a discussion concerning possible problems, such as subsurface refusal]

[Include this paragraph first if exact sampling locations are to be determined in the field; otherwise delete.]

Exact soil sampling locations will be determined in the field based on accessibility, visible signs of potential contamination (e.g., stained soils), and topographical features which may indicate location of hazardous substance disposal (e.g., depressions that may indicate a historic excavation). Soil sample locations will be recorded in the field logbook as sampling is completed. A sketch of the sample location will be entered into the logbook and any physical reference points will be labeled. If possible, distances to the reference points will be given.

[If subsurface soil samples are to be analyzed for volatile compounds, use this paragraph; otherwise delete.]

Samples to be analyzed for volatile organic compounds will be collected first. Subsurface samples will be collected by boring to the desired sample depth using ________________________ __________________ [whatever method is appropriate or available]. Once the desired sample depth is reached, soil samples for VOC analyses will be collected as independent, discrete samples. Surface soil samples will be collected using a 5 gram Encore sampling device, and will be collected in triplicate. Samples will be sealed using the Encore sampler and a zip lock bag or else transferred directly from the sampler into a VOA vial containing either 10 mLs of methanol or sodium bisulfate solution. Sample containers will be closed as soon as they are filled, chilled immediately to 4°C before wrapping them in bubble wrap, and processed for shipment to the laboratory. [If subsurface soil samples are being collected for other than volatile organic compounds, use these paragraphs; otherwise delete.]

Subsurface samples will be collected by boring to the desired sample depth using _________________

_______________________________ [whatever method is appropriate or available]. Once the desired sample depth is reached, the _______________________________ [hand- or power-operated device, such as a shovel, hand auger, trier, hollow-stem auger or split-spoon sampler] will be inserted into the hole and used to collect the sample. Samples will be transferred from the ______________________ [sampling device] to a sample-dedicated disposable pail and homogenized with a trowel.

Material in the pail will be transferred with a trowel from the pail to the appropriate sample containers. Sample containers will be filled to the top taking care to prevent soil from remaining in the lid threads prior to being sealed to prevent potential contaminant migration to or from the sample. After sample containers are filled, they will be immediately sealed, chilled if appropriate, and processed for shipment to the laboratory. [Include this as the final paragraph regardless of the analyses for subsurface soil samples.] Excess set-aside soil from the above the sampled interval will then be repacked into the hole.

6.4. Sediment Sampling

[Use this subsection if sediment samples are to be collected. Specify the method (e.g., dredges) that will be used to collect the samples and at what depth samples will be collected. Describe how samples will be homogenized and the method to be used to transfer samples to the appropriate containers. If a SOP will be followed rather than the language provided, the SOP should be referenced and included in the appendix.]

[If exact sediment sampling locations will be determined in the field, this should be stated. Describe where sediment samples will be collected, e.g., slow moving portions of streams, lake bottoms, washes, etc.]

Exact sediment sampling locations will be determined in the field, based on ____________________ ____________________________________ [Describe the criteria to be used to determine sampling locations]. Care will be taken to obtain as representative a sample as possible. The sample will be taken from areas likely to collect sediment deposits, such as slow moving portions of streams or from the bottom of the lake at a minimum depth of .6 meters. Sediment samples will be collected from the well bottom at a depth of _______ inches using a pre-cleaned __________ sampler.

[The final paragraph describes sample homogenization, especially important if the sample is to be separated into solid and liquid phases, and container filling. Include this paragraph, or a modified form of it, for all sediment sampling. It is assumed that sediment samples will not be analyzed for volatile compounds. If sediment is to be analyzed for volatile organic compounds, the samples to be analyzed for volatile compounds should not be homogenized, but rather transferred directly from the sampler into the sample container. If feasible, an Encore sampling device should be used.]

Material in the sampler will be transferred to a sample-dedicated disposable pail and homogenized with a trowel. Material from the pail will be transferred with a trowel from the bucket to the appropriate sample containers. Sample containers will be filled to the top taking care to prevent soil from remaining in the lid groves prior to being sealed in order to prevent potential contamination migration to or from the sample containers. After sample containers are filled, they will be immediately sealed, chilled if appropriate, and processed for shipment to the laboratory.

6.5. Water Sampling

6.5.1 *Surface Water Sampling*

[Use this subsection if samples are to be collected in rivers, streams, lakes and reservoirs, or from standing water in runoff collection ponds, gullies, drainage ditches, etc. Describe the sampling procedure, including the type of sample (grab or composite - see definitions below), sample bottle preparation, and project-specific directions for taking the sample. State whether samples will be collected for chemical and/or microbiological analyses. Alternatively, reference the appropriate sections of attached SOPs.]

Grab: Samples will be collected at one time from one location. The sample should be taken from flowing, not stagnant water, and the sampler should be facing upstream in the middle of the stream. Samples will be collected by hand or with a sample bottle holder. For samples taken at a single depth, the bottle should be uncapped and the cap protected from contamination. The bottle should be plunged into the water mouth down and filled 15 to 30 centimeters below the surface of the water. If it is important to take samples at depths, special samplers (e.g., Niskin or Kemmerer Depth Samplers) may be required. After filling the bottle(s), pour out some sample leaving a headspace of 2.5-5cm. For microbiological samples, bottles and caps must be sterile. If sampling of chlorinated water is anticipated, sodium thiosulfate at a concentration of 0.1 mL of a 10% solution for each 125 mL (4 oz) of sample volume must be put into the bottle before it is sterilized. Time Composite: Samples are collected over a period of time, usually 24 hours. If a composite sample is required, a flow- and time-proportional automatic sampler should be positioned to take samples at the appropriate location in a manner such that the sample can be held at 4oC for the duration of the sampling.

Spatial Composite: Samples are collected from different representative positions in the water body and combined in equal amounts. A Churn Splitter or equivalent device will be used to ensure that the sample is homogeneously mixed before the sample bottles are filled. Volatile organic compound samples will be collected as discrete samples and not composited. [If exact surface water sample locations will be determined in the field, this should be stated. Describe the criteria that will be used to determine where surface water samples will be collected.]

6.5.2 *Groundwater Sampling*

[This subsection contains procedures for water level measurements, well purging, and well sampling. Relevant procedures should be described under this heading with any necessary site-specific modifications. Alternatively, reference appropriate SOP(s).]

6.5.2.1. Water-Level Measurements

[The following language may be used as is or modified to meet project needs.]

All field meters will be calibrated according to manufacturer's guidelines and specifications before and after every day of field use. Field meter probes will be decontaminated before and after use at each well. If well heads are accessible, all wells will be sounded for depth to water from top of casing and total well depth prior to purging. An electronic sounder, accurate to the nearest +/- cm, will be used to measure depth to water in each well. When using an electronic sounder, the probe is lowered down the casing to the top of the water column; the graduated markings on the probe wire or tape are used to measure the depth to water from the surveyed point on the rim of the well casing. Typically, the measuring device emits a constant tone when the probe is submerged in standing water and most electronic water level sounders have a visual indicator consisting of a small light bulb or diode that turns on when the probe encounters water. Total well depth will be sounded from the surveyed top of casing by lowering the weighted probe to the bottom of the well. The weighted probe will sink into silt, if present, at the bottom of the well screen. Total well depths will be measured by lowering the weighted probe to the bottom of the well and recording the depth to the nearest centimeter. Water-level sounding equipment will be decontaminated before and after use in each well. Water levels will be measured in wells which have the least amount of known contamination first. Wells with known or suspected contamination will be measured last.

6.5.2.2. Purging

[Describe the method that will be used for well purging (e.g., dedicated well pump, bailer, hand pump). Reference the appropriate sections in the Ground Water SOP and state in which Appendix the SOP is located.]

[VERSION A]
All wells will be purged prior to sampling. If the well casing volume is known, a minimum of three casing volumes of water will be purged using the dedicated well pump.

[VERSION B]
All wells will be purged prior to sampling. If the well casing volume is known, a minimum of three casing volumes of water will be purged using a hand pump, submersible pump, or bailer, depending on the diameter and configuration of the well. When a submersible pump is used for purging, clean flexible Teflon tubes will be used for groundwater extraction. All tubes will be decontaminated before use in each well. Pumps will be placed 0.66 to 1 meter from the bottom of the well to permit reasonable drawdown while preventing cascading conditions.

[VERSION C]
All wells will be purged prior to sampling. If the well casing volume is known, a minimum of three casing volumes of water will be purged using the dedicated well pump, if present, or a bailer, hand pump, or submersible pump depending on the diameter and configuration of the well. When a submersible pump is used for purging, clean flexible Teflon tubes will be used for groundwater extraction. All tubes will be decontaminated before use in each well. Pumps will be placed 0.66 to 1 meter from the bottom of the well to permit reasonable draw down while preventing cascading conditions.

[ALL VERSIONS - to be included in all sample plans]
Water will be collected into a measured bucket to record the purge volume. Casing volumes will be calculated based on total well depth, standing water level, and casing diameter.

It is most important to obtain a representative sample from the well. Stable water quality parameter (temperature, pH and specific conductance) measurements indicate representative sampling is obtainable. Water quality is considered stable if for three consecutive readings:

- Temperature range is no more than +1/C;
- pH varies by no more than 0.2 pH units;
- Specific conductance readings are within 10% of the average.

The water in which measurements were taken will not be used to fill sample bottles. If the well casing volume is known, measurements will be taken before the start of purging, in the middle of purging, and at the end of purging each casing volume. If the well casing volume is NOT known, measurements will be taken every 2.5 minutes after flow starts. If water quality parameters are not stable after 5 casing volumes or 30 minutes, purging will cease, which will be noted in the logbook, and ground water samples will be taken. The depth to water, water quality measurements and purge volumes will be entered in the logbook. If a well dewaters during purging and three casing volumes are not purged, that well will be allowed to recharge up to 80% of the static water column and dewatered once more. After water levels have recharged to 80% of the static water column, groundwater samples will be collected.

6.5.2.3. Well Sampling

[Describe the method that will be used to collect samples from wells. (This will probably be the same method as was used to purge the wells.) Specify the sequence for sample collection (e.g., bottles for volatile analysis will be filled first, followed by semi-volatiles, etc.). State whether samples for metals analysis will be filtered or unfiltered. Include the specific conditions, such as turbidity, that will require samples to be filtered. Alternatively, reference the appropriate sections in the Ground Water SOP and state in which Appendix the SOP is located.]

ALL VERSIONS - to be included in all sample plans]
At each sampling location, all bottles designated for a particular analysis (e.g., trace metals) will be filled sequentially before bottles designated for the next analysis are filled. If a duplicate sample is to be collected at this location, all bottles designated for a particular analysis for both sample designations will be filled sequentially before bottles for another analysis are filled. Groundwater samples will be transferred from the tap directly into the appropriate sample containers with preservative, if required, chilled if appropriate, and processed for shipment to the laboratory. When transferring samples, care will be taken not to touch the tap to the sample container. [If samples are to be collected for volatiles analysis, the following paragraph should be added; otherwise delete.]

Samples for volatile organic compound analyses will be collected using a low flow sampling device. A [specify type of pump] pump will be used at a flow rate of ______. Vials for volatile organic compound analysis will be filled first to minimize the effect of aeration on the water sample. A test vial will be filled with sample, preserved with hydrochloric acid (HCl) and tested with pH paper to determine the amount of preservative needed to lower the pH to less than 2. The appropriate amount of HCl will then be added to the sample vials prior to the addition of the sample. The vials will be filled directly from the tap and capped. The vial will be inverted and checked for air bubbles to ensure zero headspace. If a bubble appears, the vial will be discarded and a new sample will be collected. [If some samples for metals (or other) analysis are to be filtered, depending upon sample turbidity, the following paragraph should be added; otherwise delete.]

After well purging and prior to collecting groundwater samples for metals analyses, the turbidity of the groundwater extracted from each well will be measured using a portable turbidity meter. A small quantity of groundwater will be collected from the well using the tap and a small amount of water will be transferred to a disposable vial and a turbidity measurement will be taken. The results of the turbidity measurement will be recorded in the field logbook. The water used to measure turbidity will be discarded after use. If the turbidity of the groundwater from a well is above 5 Nephelometric Turbidity Units (NTUs), both a filtered and unfiltered sample will be collected. A [specify size]-micron filter will be used to remove larger particles that have been entrained in the water sample. A sample-dedicated Teflon tube will be attached to the tap closest to the well head. The filter will be attached to the outlet of the Teflon tube. A clean, unused filter will be used for each filtered sample collected. Groundwater samples will be transferred from the filter directly into the appropriate sample containers with a preservative and processed for shipment to the laboratory. When transferring samples, care will be taken not to touch the filter to the sample container. After the filtered sample has been collected, the Teflon tube and filter will be removed and an unfiltered sample will be collected. A sample number appended with an "Fl" will represent a sample filtered with a 5-micron filter.

[If samples are to be filtered for metals (or other) analysis regardless of sample turbidity, the following paragraph should be added; otherwise delete.]

Samples designated for metals analysis will be filtered. A 5-micron filter will be used to remove larger particles that have been entrained in the water sample. A sample-dedicated Teflon tube will be attached to the tap closest to the well head. The filter will be attached to the outlet of the Teflon tube. A clean, unused filter will be used for each filtered sample collected. Groundwater samples will be transferred from the filter directly into the appropriate sample containers to which preservative has been added and processed for shipment to the laboratory. When transferring samples, care will be taken not to touch the filter to the sample container. After the filtered sample has been collected, the Teflon tube and filter will be removed and an unfiltered sample will be collected. A sample number appended with an "Fl" will represent a sample filtered with a 5-micron filter.

6.6. Biological Sampling

For the purpose of this guidance, biological sampling falls into two categories. Other types of biological sampling events should be discussed with the QA Office to determine what type of planning document is needed. The two types addressed in this guidance are biological samples being collected for chemical analysis and biological samples for the purpose of assessing species diversity. If the latter type of sampling is planned, a quality assurance project plan may be a more appropriate document. Samples collected for microbiological analyses should be discussed under water sampling.

6.6.1 *Biological Sampling for Chemical Analysis*

[The two most common types of biological samples being collected for chemical analysis are fish and foliage samples. The following paragraphs are suggested, but field circumstances may dictate alternative collection procedures; if no biological samples will be collected, put “not applicable” by these sections. If a SOP will be followed, include it in the appendix.]

6.6.1.1. Fish Samples

[Use if collecting fish, otherwise delete. Alternatively, reference appropriate SOPs.] Fish will be collected using ______________________ [name method; nets, electro-shocking, lines, etc.]. Three fish of each type or species ______________________ [indicate type of fish, e. g., trout, catfish, etc.] will be collected. Efforts will be made to collect fish of approximately the same size and maturity by checking to make sure that lengths and weights do not differ by more than 20%. Once collected the ____________________________ [indicate whether whole fish or filets] will be frozen, wrapped in aluminum foil and plastic bags and sent to a laboratory.]

[If samples are to be composited by the laboratory, also indicate that in this section.]

6.6.1.2. Foliage Samples

[Use if collecting foliage samples, otherwise delete. This section may require considerable modification because of the potential diversity of projects involving plants sampling.]

A representative foliage sample will be collected from the target area. It is recommended that a statistical approach be used, if possible. The following plants will be collected: ___________, ___________, and _____________. These plants are being collected because they are most likely affected by chemicals used in the area. Only foliage showing visible signs of stress or damage will be collected. Stems and twigs will be discarded; leaves only will be collected. The same type of leaf material [Describe material, mature leaves, young shoots, etc.] will be obtained from each plant type. Provided contamination is uniform, material will be composited from several plants to yield a total of about [specify quantity] pound(s) of material. Control samples will also be collected from a nearby unaffected area [Describe area], if available. Latex gloves will be worn during the collection of all samples. Samples will be stored in [describe container, plastic bags, bottles, etc.] and brought to the laboratory as soon as possible to prevent sample deterioration.

6.6.2 *Biological Sampling for Species Assessment*

[Describe the collection of insects, other invertebrates, or other types of biological samples here. Reference or attach appropriate protocols to support the sampling effort.]

6.7. Decontamination Procedures

[Specify the decontamination procedures that will be followed if non-dedicated sampling equipment is used. Alternatively, reference the appropriate sections in the organization's Decontamination Standard Operating Procedure.]

The decontamination procedures that will be followed are in accordance with approved procedures. Decontamination of sampling equipment must be conducted consistently as to assure the quality of samples collected. All equipment that comes into contact with potentially contaminated soil or water will be decontaminated. Disposable equipment intended for one-time use will not be decontaminated, but will be packaged for appropriate disposal. Decontamination will occur prior to and after each use of a piece of equipment. All sampling devices used, including trowels and augers, will be steam-cleaned or decontaminated according to the following decontamination procedures:

[Use the following decontamination procedures, if samples are collected for organic analyses only; otherwise delete.]

- Non-phosphate detergent and tap water wash, using a brush if necessary.
- Tap-water rinse.
- Deionized/distilled water rinse.
- Pesticide-grade solvent (reagent grade hexane) rinse in a decontamination bucket.
- Deionized/distilled water rinse (twice).

[Use the following decontamination procedures if samples are collected for inorganic (metals) analyses only, otherwise delete.]

- Non-phosphate detergent and tap water wash, using a brush if necessary.
- Tap-water rinse.
- 0.1 N nitric acid rinse.
- Deionized/distilled water rinse (twice).

[Use the following decontamination procedures if samples are collected for both organic and inorganic analyses, otherwise delete.]

- Non-phosphate detergent and tap water wash, using a brush if necessary.

- Tap-water rinse.
- 0.1 N nitric acid rinse.
- Deionized/distilled water rinse.
- Pesticide-grade solvent (reagent grade hexane) rinse in a decontamination bucket.
- Deionized/distilled water rinse (twice).

Equipment will be decontaminated in a predesignated area on pallets or plastic sheeting, and clean bulky equipment will be stored on plastic sheeting in uncontaminated areas. Cleaned small equipment will be stored in plastic bags. Materials to be stored more than a few hours will also be covered.

[NOTE: A different decontamination procedure may be used; but if so, a rationale for using the different approach should be provided.]

7 SAMPLE CONTAINERS, PRESERVATION AND STORAGE

[This section requires a reference to the types of bottles to be used, preparation and preservatives to be added. The organization responsible for adding preservatives should be named. If the information is provided in the request for analyses tables, reference them in the appropriate section below.]

The number of sample containers, volumes, and materials are listed in Section 5.0. The containers are pre-cleaned and will not be rinsed prior to sample collection. Preservatives, if required, will be added by _______ [name of agency/organization doing the sampling] to the containers prior to shipment of the samples to the laboratory.

7.1. Soil Samples

[If soil samples are to be collected, specify the analyses that will be performed. Use the language below or reference the appropriate sections in the Preservation SOP and state in which Appendix the SOP is located.]

[Include this subsection if collecting soil samples; otherwise delete.]

[If requested analyses include analyses other than volatile organic compounds or metals, include this paragraph; otherwise delete.]

Soil samples for ______________ [Include all requested analysis(es), e.g., Pesticides, Semi-volatile Organic Compounds] will be homogenized and transferred from the sample-dedicated homogenization pail into 8-ounce (oz), wide-mouth glass jars using a trowel. For each sample, one 8-oz wide-mouth glass jar will be collected for each laboratory. Alternatively, sample will be retained in the brass sleeve in which collected until sample preparation begins. The samples will be chilled to 4/C immediately upon collection.

[If requested analyses include volatile organic compounds, include this paragraph; otherwise delete.]

VOLATILE ORGANIC COMPOUNDS. Soil samples to be analyzed for volatile organic compounds will be stored in their sealed Encore samplers for no more than two days prior to analysis. Frozen Encore sampler samples will be stored for no more than 4 days prior to analysis. If samples are preserved by ejecting into either methanol or sodium bisulfate solution the holding time is two weeks. Preserved samples will be chilled to 4/C immediately upon collection.

[If requested analyses include metals, include this paragraph; otherwise delete.]

METALS. Surface soil samples to be analyzed for metals will be homogenized and transferred from the sample-dedicated homogenization pail into 8-oz, wide-mouth glass jars. For each sample, one 8-oz glass jar will be collected for each laboratory. Samples will not be chilled. Subsurface samples will be retained in their original brass sleeves or other container unless transferred to bottles.

7.2. Sediment Samples

[If sediment samples are to be collected, specify the analyses that will be performed. Use the language below or reference the appropriate sections in a Preservation SOP and state in which Appendix the SOP is located.]

[If requested analyses include analyses other than volatile organic compounds or metals, include this paragraph; otherwise delete.]

_______________ [Include all requested analysis(es), e.g., Pesticides, Semi-volatile Organic Compounds]. Sediment samples will be homogenized and transferred from the sample-dedicated homogenization pail into 8-oz wide-mouth glass jars. For each sample, one 8-oz glass jar will be collected for each laboratory.

The samples will be chilled to 4/C immediately upon collection.

[If requested analyses include volatile organic compounds, include this paragraph; otherwise delete.]

VOLATILE ORGANIC COMPOUNDS. Sediment samples to be analyzed for volatile organic compounds will be stored in their sealed Encore samplers for no more than two days prior to analysis. Frozen Encore sampler samples will be stored for no more than 4 days prior to analysis. If samples are preserved by ejecting into either methanol or sodium bisulfate solution the holding time is two weeks. Preserved samples will be chilled to 4/C immediately upon collection.

[If requested analyses include metals, include this paragraph; otherwise delete.]

METALS. Sediment samples, with rocks and debris removed, which are to be analyzed for metals will be homogenized and transferred from the sample-dedicated homogenization pail into 8-oz, wide-mouth glass jars. For each sample, one 8-oz glass jar will be collected for each laboratory. Samples will not be chilled.

7.3. Water Samples

[If water samples are to be collected, specify the analyses that will be performed. Use the language below or else reference the appropriate sections in a Preservation SOP and state in which Appendix the SOP is located.]

[Include this subsection if collecting water samples; otherwise delete.]

Depending on the type of analysis (organic or inorganic) requested, and any other project-specific analytical requirements, sample bottles should be plastic (inorganics) or glass (organics), pre-cleaned (general decontamination procedures) or low-detection level pre-cleaned (extensive decontamination procedures).

[Describe the type of bottles that will be used for the project, including the cleaning procedures that will be followed to prepare the bottles for sampling.]

[If requested analyses do not require preservation, include this paragraph; otherwise delete. A separate paragraph should be included for each bottle type.]

______________ [Include all requested analysis(es), e.g., Anions, Pesticides, Semi-volatile Organic Compounds]. Low concentration water samples to be analyzed for ______________ [Specify analysis(es), e.g., Semi-volatile Organic Compounds] will be collected in ____________ [Specify bottle type, e. g., 1-liter (L) amber glass bottles]. No preservative is required for these samples. The samples will be chilled to 4/C immediately upon collection. Two bottles of each water sample are required for each laboratory.

[If requested analyses include volatile organic compounds, include this paragraph; otherwise delete.]

VOLATILE ORGANIC COMPOUNDS. Low concentration water samples to be analyzed for volatile organic compounds will be collected in 40-mL glass vials. 1:1 hydrochloric acid (HCl) will be added to the vial prior to sample collection. During purging, the pH will be measured using a pH meter to test at least one vial at each sample location to ensure sufficient acid is present to result in a pH of less than 2. The tested vial will be discarded. If the pH is greater than 2, additional HCl will be added to the sample vials. Another vial will be pH tested to ensure the pH is less than 2. The tested vial will be discarded. The vials will be filled so that there is no headspace. The samples will be chilled to 4/C immediately upon collection. Three vials of each water sample are required for each laboratory.

[If requested analyses include metals, include this paragraph; otherwise delete.]

METALS. Water samples collected for metals analysis will be collected in 1L polyethylene bottles. The samples will be preserved by adding nitric acid (HNO3) to the sample bottle. The bottle will be capped and lightly shaken to mix in the acid. A small quantity of sample will be poured into the bottle cap where the pH will be measured using pH paper. The pH must be <2. The sample in the cap will be discarded, and the pH of the sample will be adjusted further if necessary. The samples will be chilled to 4/C immediately upon collection. One bottle of each water sample is required for each laboratory.

GENERAL CHEMISTRY (WATER QUALITY) PARAMETERS. Water samples collected for water quality analysis [Specify what parameters are included. Examples include (but are not limited to) anions (nitrate-N, nitrite-N, sulfate, phosphate), total phosphorus, ammonia-N, total dissolved solids, total suspended solids, alkalinity (may include carbonate, and/or bicarbonate), hardness, cyanide, MBAS (methylene blue active substances), etc.], will be collected in [Specify size of container] polyethylene bottles. The [Specify analysis] samples will be preserved by adding [Describe preservative appropriate to each sample type] to the sample bottle. The [Specify analysis] samples will not be preserved. If preservative is added, the bottle will be capped and lightly shaken to mix in the preservative. Where the preservative affects the pH, a small quantity of sample will be poured into the bottle cap where the pH will be measured using pH paper. The pH must be within the appropriate range. The sample in the cap will be discarded, and the pH of the sample will be adjusted further if necessary. Samples will be chilled to 4/C immediately upon collection. Samples from each location that require the same preservative will be placed in the same bottle if being analyzed by the same laboratory.

7.4. Biological Samples

[If biological samples are to be collected, specify the analyses that will be performed. Use the language below or reference the appropriate sections in a Preservation SOP and state in which Appendix the SOP is located.]

7.4.1. *Fish Samples*

Fish (whole or fillets) will be wrapped in aluminum foil, labeled, and placed in individual zip lock bags. The samples will be frozen as quickly as possible and shipped using dry ice to maintain the frozen state.

7.4.2. *Foliage Samples*

[Describe the containers that will be used for the project. Usually foliage samples are collected in clean zip lock bags, but bottles or other containers can be used. Paper bags are not recommended.]

For foliage samples, samples will be collected in a large zip Lock bag. A self adhesive label will be placed on each bag and the top sealed with a custody seal

7.4.3. *Biological Sampling for Species Assessment*

[Describe the containers in which macroinvertebrates, insects and other biological samples will be stored. If a fixation liquid will be used, it should be described as well. This section should also discuss any special handling procedures which must be followed to minimize damage to the specimens.]

8 DISPOSAL OF RESIDUAL MATERIALS

[This section should describe the type(s) of investigation- derived wastes (IDW) that will be generated during this sampling event. IDW may not be generated in all sampling events, in which case this section would not apply. Use the language below or reference the appropriate sections in a Disposal of Residual Materials SOP and state in which Appendix the SOP is located. Depending upon site-specific conditions and applicable federal, state, and local regulations, other provisions for IDW disposal may be required. If any analyses of IDW are required, these should be discussed. If IDW are to be placed in drums, labeling for the drums should be discussed in this section.]

In the process of collecting environmental samples at the _________ [site or sampling area name] during the site investigation (SI) [or name of other investigation]; the ________ [name of your organization/agency] sampling team will generate different types of potentially contaminated IDW that include the following:

- Used personal protective equipment (PPE).
- Disposable sampling equipment.
- Decontamination fluids [Include this bullet when sampling soils; otherwise delete.]
- Soil cuttings from soil borings [Include this bullet when sampling groundwater; otherwise delete.]
- Purged groundwater and excess groundwater collected for sample container filling.

[The following bullet is generally appropriate for site or sampling areas with low levels of contamination or for routine monitoring. If higher levels of contamination exist at the site or sampling area, other disposal methods (such as the drumming of wastes) should be used to dispose of

used PPE and disposable sampling equipment.]

- Used PPE and disposable equipment will be double bagged and placed in a municipal refuse dumpster. These wastes are not considered hazardous and can be sent to a municipal landfill. Any PPE and disposable equipment that is to be disposed of which can still be reused will be rendered inoperable before disposal in the refuse dumpster. [Include this bullet if sampling for both metals and organics; otherwise delete.]
- Decontamination fluids that will be generated in the sampling event will consist of dilute nitric acid, pesticide-grade solvent, deionized water, residual contaminants, and water with non-phosphate detergent. The volume and concentration of the decontamination fluid will be sufficiently low to allow disposal at the site or sampling area. The water (and water with detergent) will be poured onto the ground or into a storm drain. Pesticide-grade solvents will be allowed to evaporate from the decontamination bucket. The nitric acid will be diluted and/or neutralized with sodium hydroxide and tested with pH paper before pouring onto the ground or into a storm drain. [Include this bullet if sampling for metals but not organics; otherwise delete.]
- Decontamination fluids that will be generated in the sampling event will consist of nitric acid, deionized water, residual contaminants, and water with non-phosphate detergent. The volume and concentration of the decontamination fluid will be sufficiently low to allow disposal at the site or sampling area. The water (and water with detergent) will be poured onto the ground or into a storm drain. The nitric acid will be diluted and/or neutralized with sodium hydroxide and tested with pH paper before pouring onto the ground or into a storm drain. [Include this bullet if sampling for organics but not metals; otherwise delete.]
- Decontamination fluids that will be generated in the sampling event will consist of pesticide-grade solvent, deionized water, residual contaminants, and water with non-phosphate detergent. The volume and concentration of the decontamination fluid will be sufficiently low to allow disposal at the site or sampling area. The water (and water with detergent) will be poured onto the ground or into a storm drain. Pesticide-grade solvents will be allowed to evaporate from the decontamination bucket. [Include this bullet if sampling soils; otherwise delete.]
- Soil cuttings generated during the subsurface sampling will be disposed of in an appropriate manner. [Include this bullet if sampling groundwater; otherwise delete.]
- Purged groundwater will be ______________ [depending upon the degree of groundwater contamination, site-specific conditions, and applicable federal, state, and local regulations, disposal methods will vary. Disposal methods can also vary for purge water from different wells sampled during the same sampling event.]

9 SAMPLE DOCUMENTATION AND SHIPMENT

9.1. Field Notes

This section should discuss record keeping in the field. This may be through a combination of logbooks, preprinted forms, photographs, or other documentation. Information to be maintained is provided below.

9.1.1 *Field Logbooks*

[Describe how field logbooks will be used and maintained.]

Use field logbooks to document where, when, how, and from whom any vital project information was *obtained. Logbook entries should be complete and accurate enough to permit reconstruction of field activities. Maintain a separate logbook for each sampling event or project. Logbooks should have consecutively numbered pages. All entries should be legible, written in black ink, and signed by the individual making the entries. Use factual, objective language.*

At a minimum, the following information will be recorded during the collection of each sample:
[Edit this list as relevant.]

- Sample location and description;
- Site or sampling area sketch showing sample location and measured distances;
- Sampler's name(s);
- Date and time of sample collection;
- Designation of sample as composite or grab;
- Type of sample (soil, sediment or water);
- Type of sampling equipment used;
- Field instrument readings and calibration;
- Field observations and details related to analysis or integrity of samples (e.g., weather conditions, noticeable odors, colors, etc.);
- Preliminary sample descriptions (e.g., for soils: clay loam, very wet; for water: clear water with strong ammonia-like odor);
- Sample preservation;
- Lot numbers of the sample containers, sample identification numbers and any explanatory codes, and chain-of-custody form numbers;
- Shipping arrangements (overnight air bill number);
- Name(s) of recipient laboratory(ies).

In addition to the sampling information, the following specific information will also be recorded in the field logbook for each day of sampling: [Edit this list as relevant.]

- Team members and their responsibilities;
- Time of arrival/entry on site and time of site departure;
- Other personnel on site;
- Summary of any meetings or discussions with contractor, or federal agency personnel;
- Deviations from sampling plans, site safety plans, and QAPP procedures;
- Changes in personnel and responsibilities with reasons for the changes;
- Levels of safety protection;
- Calibration readings for any equipment used and equipment model and serial number.

[A checklist of the field notes, following the suggestions above, using only those that are appropriate, should be developed and included in project field notes.]

9.1.2 *Photographs*

[If photographs will be taken, the following language may be used as is or modified as appropriate.]

Photographs will be taken at the sampling locations and at other areas of interest on site or sampling area. They will serve to verify information entered in the field logbook. For each photograph taken, the following information will be written in the logbook or recorded in a separate field photography log:

- Time, date, location, and weather conditions;
- Description of the subject photographed;

- Name of person taking the photograph.

9.2. Labeling

[The following paragraph provides a generic explanation and description of the use of labels. It may be incorporated as is, if appropriate, or modified to meet any project-specific conditions.]

All samples collected will be labeled in a clear and precise way for proper identification in the field and for tracking in the laboratory. A copy of the sample label is included in Appendix __. The samples will have preassigned, identifiable, and unique numbers. At a minimum, the sample labels will contain the following information: station location, date of collection, analytical parameter(s), and method of preservation. Every sample, including samples collected from a single location but going to separate laboratories, will be assigned a unique sample number.

9.3. Sample Chain-Of-Custody Forms and Custody Seals

[The following paragraphs provide a generic explanation and description of the use of chain-of-custody forms and custody seals. They may be incorporated as is, if they are appropriate, or modified to meet any project-specific conditions.]

Organic and inorganic chain-of-custody record/traffic report forms are used to document sample collection and shipment to laboratories for analysis. All sample shipments for analyses will be accompanied by a chain-of-custody record. A copy of the form is found in Appendix. Form(s) will be completed and sent with the samples for each laboratory and each shipment (i.e., each day). If multiple coolers are sent to a single laboratory on a single day, form(s) will be completed and sent with the samples for each cooler.

The chain-of-custody form will identify the contents of each shipment and maintain the custodial integrity of the samples. Generally, a sample is considered to be in someone's custody if it is either in someone's physical possession, in someone's view, locked up, or kept in a secured area that is restricted to authorized personnel. Until the samples are shipped, the custody of the samples will be the responsibility of _____ [name of agency/ organization conducting sampling]. The sampling team leader or designee will sign the chain-of-custody form in the "relinquished by" box and note date, time, and air bill number. The sample numbers for all reference samples, laboratory QC samples, and duplicates will be documented on this form (see Section 10.0). A photocopy will be made for the _____'s [name of agency/ organization conducting sampling] master files.

A self-adhesive custody seal will be placed across the lid of each sample. A copy of the seal is found in Appendix _. For VOC samples, the seal will be wrapped around the cap. The shipping containers in which samples are stored (usually a sturdy picnic cooler or ice chest) will be sealed with self-adhesive custody seals any time they are not in someone's possession or view before shipping. All custody seals will be signed and dated.

9.4. Packaging and Shipment

[The following paragraphs provide a generic explanation and description of how to pack and ship samples. They may be incorporated as is, if appropriate, or modified to meet any project-specific conditions.]

All sample containers will be placed in a strong-outside shipping container (a steel-belted cooler). The following outlines the packaging procedures that will be followed for low concentration samples.

1. When ice is used, pack it in zip-locked, double plastic bags. Seal the drain plug of the cooler with fiberglass tape to prevent melting ice from leaking out of the cooler.
2. The bottom of the cooler should be lined with bubble wrap to prevent breakage during shipment.
3. Check screw caps for tightness and, if not full, mark the sample volume level of liquid samples on the outside of the sample bottles with indelible ink.
4. Secure bottle/container tops with clear tape and custody seal all container tops.
5. Affix sample labels onto the containers with clear tape.
6. Wrap all glass sample containers in bubble wrap to prevent breakage.
7. Seal all sample containers in heavy duty plastic zip-lock bags. Write the sample numbers on the outside of the plastic bags with indelible ink.
8. Place samples in a sturdy cooler(s) lined with a large plastic trash bag. Enclose the appropriate COC(s) in a zip-lock plastic bag affixed to the underside of the cooler lid.
9. Fill empty space in the cooler with bubble wrap or Styrofoam peanuts to prevent movement and breakage during shipment.
10. Ice used to cool samples will be double sealed in two zip lock plastic bags and placed on top and around the samples to chill them to the correct temperature.
11. Each ice chest will be securely taped shut with fiberglass strapping tape, and custody seals will be affixed to the front, right and back of each cooler.

Records will be maintained by the [organization]’s sample custodian of the following information:

- Sampling contractor's name *(if not the organization itself)*;
- Name and location of the site or sampling area;
- Case or Regional Analytical Program (RAP) number;
- Total number(s) by estimated concentration and matrix of samples shipped to each laboratory;
- Carrier, air bill number(s), method of shipment (priority next day);
- Shipment date and when it should be received by lab;
- Irregularities or anticipated problems associated with the samples;
- Whether additional samples will be shipped or if this is the last shipment.

10 QUALITY CONTROL

This section should discuss the quality control samples that are being collected to support the sampling activity. This includes field QC samples, confirmation samples, background samples, laboratory QC samples, and split samples. Wherever possible, the locations at which the samples will be collected should be identified and a rationale provided for the choice of location. Frequency of collection should be discussed. All samples, except laboratory QC samples, should be sent to the laboratory blind, wherever possible. Laboratory QC samples should be identified and additional sample (e.g., a double volume) collected for that purpose.

10.1. Field Quality Control Samples

Field quality control samples are intended to help evaluate conditions resulting from field activities and are intended to accomplish two primary goals, assessment of field contamination and assessment of sampling variability. The former looks for substances introduced in the field due to environmental or sampling equipment and is assessed using blanks of different types. The latter includes variability due to sampling technique and instrument performance as well as variability possibly caused by the heterogeneity of the matrix being sampled and is assessed using replicate sample collection. The *following sections cover field QC.*

10.1.1 *Assessment of Field Contamination (Blanks)*

Field contamination is usually assessed through the collection of different types of blanks. Equipment blanks are obtained by passing distilled or deionized water, as appropriate, over or through the decontaminated equipment used for sampling. They provide the best overall means of assessing contamination arising from the equipment, ambient conditions, sample containers, transit, and the laboratory. Field blanks are sample containers filled in the field. They help assess contamination from ambient conditions, sample containers, transit, and the laboratory. Trip blanks are prepared by the laboratory and shipped to and from the field. They help assess contamination from shipping and the laboratory and are for volatile organic compounds only. Equipment blanks should be collected, where appropriate (e.g., where neither disposable nor dedicated equipment is used). Field blanks are next in priority, and trip blanks next. Only one type of blank must be collected per event, not all three.

10.1.1.1. Equipment Blanks

In general, equipment (rinsate) blanks should be collected when reusable, non-disposable sampling equipment (e.g., trowels, hand augers, and non-dedicated groundwater sampling pumps) are being used for the sampling event. Only one blank sample per matrix per day should be collected. If equipment blanks are collected, field blanks and trip blanks are not required under normal circumstances. Equipment blanks can be collected for soil, sediment, and ground water samples. A minimum of one equipment blank is prepared each day for each matrix when equipment is decontaminated in the field. These blanks are submitted "blind" to the laboratory, packaged like other samples and each with its own unique identification number. Note that for samples which may contain VOCs, water for blanks should be purged prior to use to ensure that it is organic free. HPLC water, which is often used for equipment and field blanks, can contain VOCs if it is not purged.

[If equipment blanks are to be collected describe how they are to be collected and the analyses that will be performed. A maximum of one blank sample per matrix per day should be collected, but at a rate to not exceed one blank per 10 samples. The 1:10 ratio overrides the one per day requirement. If equipment rinsate blanks are collected, field blanks and trip blanks are not required under normal circumstances. Use the language below or reference the appropriate sections in a Quality Control SOP and state in which Appendix the SOP is located.]

[Include this subsection if equipment blanks are to be collected, otherwise, delete.]

[Include this paragraph if blanks will be analyzed for both metals and organic compounds; otherwise delete.]

Equipment rinsate blanks will be collected to evaluate field sampling and decontamination procedures by pouring High Performance Liquid Chromatography (HPLC) organic-free (for organics) or deionized water (for inorganics) over the decontaminated sampling equipment. One equipment rinsate blank will be collected per matrix each day that sampling equipment is decontaminated in the field. Equipment rinsate blanks will be obtained by passing water through or over the decontaminated sampling devices used that day. The rinsate blanks that are collected will be analyzed for ________ [Include names of target analytes, e.g., metals, total petroleum hydrocarbons, volatile organic compounds, etc.].

[Include this paragraph if blanks will be analyzed only for organic compounds; otherwise delete.]

Equipment rinsate blanks will be collected to evaluate field sampling and decontamination procedures by pouring High Performance Liquid Chromatography (HPLC) organic-free water over the decontaminated sampling equipment. One equipment rinsate blank will be collected per matrix each day that sampling equipment is decontaminated in the field. Equipment rinsate blanks will be obtained by passing water through or over the decontaminated sampling devices used that day. The rinsate blanks that are collected will be analyzed for _________ [Include names of target analytes, e.g., volatile organic compounds, total petroleum hydrocarbons, etc.] [Include this paragraph if blanks will be analyzed only for metals; otherwise delete.]

Equipment rinsate blanks will be collected to evaluate field sampling and decontamination procedures by pouring deionized water over the decontaminated sampling equipment. One equipment rinsate blank will be collected per matrix each day that sampling equipment is decontaminated in the field. Equipment rinsate blanks will be obtained by passing deionized water through or over the decontaminated sampling devices used that day. The insate blanks that are collected will be analyzed for metals.

[Always include this paragraph.]The equipment rinsate blanks will be preserved, packaged, and sealed in the manner described for the environmental samples. A separate sample number and station number will be assigned to each sample, and it will be submitted blind to the laboratory.

10.1.1.2. Field Blanks

Field blanks are collected when sampling water or air and equipment decontamination is not necessary or sample collection equipment is not used (e.g., dedicated pumps). A minimum of one field blank is prepared each day sampling occurs in the field, but equipment is not decontaminated. These blanks are submitted "blind" to the laboratory, packaged like other samples and each with its own unique identification number. Note that for samples which may contain VOCs, water for blanks should be purged prior to use to ensure that it is organic free. HPLC water, which is often used for equipment and field blanks, can contain VOCs if it is not purged.

[Include this subsection if field blanks will be collected; otherwise delete. Only one blank sample per matrix per day should be collected. If field blanks are prepared, equipment rinsate blanks and trip blanks are not required under normal circumstances.]

[Include this paragraph if blanks will be analyzed for both metals and organic compounds; otherwise delete.]

Field blanks will be collected to evaluate whether contaminants have been introduced into the samples during the sampling due to ambient conditions or from sample containers. Field blank samples will be obtained by pouring High Performance Liquid Chromatography (HPLC) organic-free water (for organics) and/or deionized water (for inorganics) into a sampling container at the sampling point. The field blanks that are collected will be analyzed for _________ [Include names of target analytes, e.g., metals, volatile organic compounds, etc.].

[Include this paragraph if blanks will be analyzed only for organic compounds; otherwise delete.]

Field blanks will be collected to evaluate whether contaminants have been introduced into the samples during the sampling due to ambient conditions or from sample containers. Field blank samples will be obtained by pouring High Performance Liquid Chromatography (HPLC) organic-free water into a sampling container at the sampling point. The field blanks that are collected will be analyzed for _________ [Include names of target analytes, e.g., volatile organic compounds, total petroleum hydrocarbons, etc.].

[Include this paragraph if blanks will be analyzed only for metals; otherwise delete.]
Field blanks will be collected to evaluate whether contaminants have been introduced into the samples during the sampling due to contamination from sample containers. Field blank samples will be obtained by pouring deionized water into a sampling container at the sampling point. The field blanks that are collected will be analyzed for metals.

[Always include this paragraph.]

The field blanks will be preserved, packaged, and sealed in the manner described for the environmental samples. A separate sample number and station number will be assigned to each sample, and it will be submitted blind to the laboratory.

10.1.1.3. Trip Blanks

Trip blanks are required only if no other type of blank will be collected for volatile organic compound analysis and when air and/or water samples are being collected. If trip blanks are required, one is submitted to the laboratory for analysis with every shipment of samples for VOC analysis. These blanks are submitted "blind" to the laboratory, packaged like other samples and each with its own unique identification number. Note that for samples which may contain VOCs, water for blanks should be purged prior to use to ensure that it is organic free. Laboratory water, which is used for trip blanks, can contain VOCs if it is not purged.

[Include this subsection if trip blanks will be collected; otherwise delete. Only one blank sample per matrix per day should be collected. Trip blanks are only relevant to volatile organic compound (VOC) sampling efforts.]

Trip blanks will be prepared to evaluate if the shipping and handling procedures are introducing contaminants into the samples, and if cross contamination in the form of VOC migration has occurred between the collected samples. A minimum of one trip blank will be submitted to the laboratory for analysis with every shipment of samples for VOC analysis. Trip blanks are 40 mL vials that have been filled with HPLC-grade water that has been purged so it is VOC free and shipped with the empty sampling containers to the site or sampling area prior to sampling. The sealed trip blanks are not opened in the field and are shipped to the laboratory in the same cooler with the samples collected for volatile analyses. The trip blanks will be preserved, packaged, and sealed in the manner described for the environmental samples. A separate sample number and station number will be assigned to each trip sample and it will be submitted blind to the laboratory.

10.1.1.4. Temperature Blanks

[Include this paragraph with all plans.] For each cooler that is shipped or transported to an analytical laboratory a 40 mL VOA vial will be included that is marked "temperature blank." This blank will be used by the sample custodian to check the temperature of samples upon receipt.

10.1.2 Assessment of Field Variability (Field Duplicate or Co-located Samples)

Duplicate samples are collected simultaneously with a standard sample from the same source under identical conditions into separate sample containers. Field duplicates will consist of a homogenized sample divided in two or else a co-located sample. Each duplicate portion should be assigned its own sample number so that it will be blind to the laboratory. A duplicate sample is treated independently of its counterpart in order to assess laboratory performance through comparison of the results. At least 10% of samples collected per event should be field duplicates. At least one duplicate should be collected for each sample matrix, but their collection can be stretched out over more than one day (e.g., if it takes more than one day to reach 10 samples). Every group of analytes for which a standard sample is analyzed will also be tested for in one or more duplicate samples. Duplicate samples should be collected from areas of known or suspected contamination. Since the objective is to assess variability due to sampling technique and possible sample heterogeneity, source variability is a good reason to collect co-located samples, not to avoid their collection.

Duplicate soils samples will be collected at sample locations [identify soil sample locations from which samples will be collected for duplicate analysis].

Duplicate samples will be collected from these locations because [Add sentence(s) here explaining a rationale for collecting duplicate samples from these locations; e.g., samples from these locations are suspected to exhibit moderate concentrations of contaminants or previous sampling events have detected moderate levels of contamination at the site or sampling area at these locations.]

[Include this paragraph if collecting soil samples and analyzing for compounds other than volatiles; otherwise delete.]

Soil samples to be analyzed for __________________ [List all analytical methods for this sample event except for volatiles.] will be homogenized with a trowel in a sample-dedicated disposable pail. Homogenized material from the bucket will then be transferred to the appropriate wide-mouth glass jars for both the regular and duplicate samples. All jars designated for a particular analysis (e.g., semi-volatile organic compounds) will be filled sequentially before jars designated for another analysis are filled (e.g., metals).

[Include this paragraph if collecting soil samples and analyzing for volatiles; otherwise delete.]

Soil samples for volatile organic compound analyses will not be homogenized. Equivalent Encore samples from a colocated location will be collected identically to the original samples, assigned unique sample numbers and sent blind to the laboratory.

[Include these paragraphs if collecting sediment samples. If volatile organic compound analysis will be performed on sediment samples, modify the above paragraph for soil sample volatile analyses by changing "soil" to "sediment."]

Duplicate sediment samples will be collected at sample locations _______________ [Identify sediment sample locations from which duplicate or colocated samples for duplicate analysis will be obtained]. Duplicate samples will be collected from these locations because ________________[Add sentence(s) here explaining a rationale for collecting duplicate samples from these locations; e.g., samples from these locations are suspected to exhibit moderate concentrations of contaminants or previous sampling events have detected moderate levels of contamination at the site or sampling area at these locations.] Sediment samples will be homogenized with a trowel in a sample-dedicated 1-gallon disposable pail. Homogenized material from the bucket will then be transferred to the appropriate wide-mouth glass jars for both the regular and duplicate samples. All jars designated for a particular analysis (e.g., semi-volatile organic compounds) will be filled sequentially before jars designated for another analysis are filled (e.g., metals).

[Include this paragraph if collecting water samples.]

Duplicate water samples will be collected for water sample numbers _____________ [water sample numbers which will be split for duplicate analysis]. Duplicate samples will be collected from these locations because ________________**[Add sentence(s) here explaining a rationale for collecting duplicate samples from these locations; e.g. samples from these locations are suspected to exhibit moderate concentrations of contaminants or previous sampling events have detected moderate levels of contamination at the site or sampling area at these locations.]** When collecting duplicate water samples, bottles with the two different sample identification numbers will alternate in the filling sequence (e.g., a typical filling sequence might be, VOCs designation GW-2, VOCs designation GW-4 (duplicate of GW-2); metals, designation GW-2, metals, designation GW-4, (duplicate of GW-2) etc.). Note that bottles for one type of analysis will be filled before bottles for the next analysis are filled. Volatiles will always be filled first.

[Always include this paragraph.]

Duplicate samples will be preserved, packaged, and sealed in then same manner as other samples of the same matrix. A separate sample number and station number will be assigned to each duplicate, and it will be submitted blind to the laboratory.

10.2. Background Samples

Background samples are collected in situations where the possibility exists that there are native or ambient levels of one or more target analytes present or where one aim of the sampling event is to differentiate between on-site and off-site contributions to contamination. One or more locations are chosen which should be free of contamination from the site or sampling location itself, but have similar geology, hydrogeology, or other characteristics to the proposed sampling locations that may have been impacted by site activities. For example, an area adjacent to but removed from the site, upstream from the sampling points, or up gradient or cross gradient from the groundwater under the site. Not all sampling events require background samples.

[Specify the sample locations that have been designated as background. Include a rationale for collecting background samples from these locations and describe or reference the sampling and analytical procedures which will be followed to collect these samples.]

10.3. Field Screening and Confirmation Samples

For projects where field screening methods are used (typically defined as testing using field test kits, immunoassay kits, or soil gas measurements or equivalent, but not usually defined as the use of a mobile laboratory which generates data equivalent to a fixed laboratory), two aspects of the tests should be described. First, the QC which will be run in conjunction with the field screening method itself, and, second, any fixed laboratory confirmation tests which will be conducted. QC acceptance criteria for these tests should be defined in these sections rather than in the DQO section.

10.3.1. *Field Screening Samples*

[For projects where field screening methods are used describe the QC, samples which will be run in the field to ensure that the screening method is working properly. This usually consists of a combination of field duplicates and background (clean) samples). The discussion should specify acceptance criteria and corrective action to be taken if results are not within defined limits. Discuss confirmation tests below.]

10.3.2. *Confirmation Samples*

If the planned sampling event includes a combination of field screening and fixed laboratory confirmation, this section should describe the frequency with which the confirmation samples will be collected and the criteria which will be used to select confirmation locations. These will both be dependent on the use of the data in decision making. It is recommended that the selection process be at a minimum of 10% and that a selection criteria include checks for both false positives (i.e., the field detections are invalid or the concentrations are not accurate) and false negatives (i.e., the analyte was not detected in the field). Because many field screening techniques are less sensitive than laboratory methods false negative screening is especially important unless the field method is below the action level for any decision making. It is recommended that some "hits" be chosen and that other locations be chosen randomly.

[Describe confirmation sampling. Discuss the frequency with which samples will be confirmed and how location will be chosen. Define acceptance criteria for the confirmation results (e.g., RPD#25%) and corrective actions to be taken if samples are not confirmed.]

10.3.3. *Split Samples*

Split Samples are defined differently by different organizations, but for the purpose of this guidance, s split samples are samples that are divided among two or more laboratory for the purpose of providing an inter-laboratory or inter-organization comparison. Usually one organization (for example, a responsible party) collects the samples and provides sufficient material to the other organization (for example, EPA) to enable it to perform independent analyses. It is expected that the sampling party will have prepared a sampling plan which the QA Office has reviewed and approved that describes the sampling locations and a rationale for their choice, sampling methods, and analyses.

[Describe the purpose of the split sampling. Include references to the approved sampling plan of the party collecting the samples. Provide a rationale for the sample locations at which split samples will be obtained and how these locations are representative of the sampling event as a whole. Describe how results are to be compared and define criteria by which agreement will be measured. Discuss corrective action to be taken if results are found to not be in agreement.]

10.4. Laboratory Quality Control Samples

Laboratory quality control (QC) samples are analyzed as part of standard laboratory practice. The laboratory monitors the precision and accuracy of the results of its analytical procedures through analysis of QC samples. In part, laboratory QC samples consist of matrix spike/matrix spike duplicate samples for organic analyses, and matrix spike and duplicate samples for inorganic analyses. The term "matrix" refers to use of the actual media collected in the field (e.g., routine soil and water samples).

Laboratory QC samples are an aliquot (subset) of the field sample. They are not a separate sample, but a special designation of an existing sample.

[Include the following language if soil samples are to be collected for other than VOCs. Otherwise delete.]

A routinely collected soil sample (a full 8-oz sample jar or two 120-mL sample vials) contains sufficient volume for both routine sample analysis and additional laboratory QC analyses. Therefore, a separate soil sample for laboratory QC purposes will not be collected. [Include the following language if soil samples are to be collected for other than VOCs. Otherwise delete.] Soil samples for volatile organic compound analyses for laboratory QC purposes will be obtained by collecting double the number of equivalent Encore samples from a colocated location in the same way as the original samples, assigned a unique sample numbers and sent blind to the laboratory.

[Include the following language if water samples are to be collected. Otherwise delete.]

For water samples, double volumes of samples are supplied to the laboratory for its use for QC purposes. Two sets of water sample containers are filled and all containers are labeled with a single sample number.

For VOC samples this would result in 6 vials being collected instead of 3, for pesticides and semi-volatile samples this would be 4 liters instead of 2, etc.

The laboratory should be alerted as to which sample is to be used for QC analysis by a notation on the sample container label and the chain-of-custody record or packing list. At a minimum, one laboratory QC sample is required per 14 days or one per 20 samples (including blanks and duplicates), whichever is greater. If the sample event lasts longer than 14 days or involves collection of more than 20 samples per matrix, additional QC samples will be designated.

For this sampling event, samples collected at the following locations will be the designated laboratory QC samples: [If a matrix is not being sampled, delete the reference to that matrix.]

- For soil, samples _____________ [List soil sample locations and numbers designated for QA/QC.]
- For sediment, samples _____________ [List sediment sample locations and numbers designated for QA/QC.]
- For water, samples _____________ [List water sample locations and numbers designated for QA/QC.]

[Add a paragraph explaining why these sample locations were chosen for QA/QC samples. QA/QC samples should be samples expected to contain moderate levels of contamination. A rationale should justify the selection of QA/QC samples based on previously-detected contamination at the site or sampling area, historic site or sampling area operations, expected contaminant deposition/migration, etc.]

11 FIELD VARIANCES

[It is not uncommon to find that, on the actual sampling date, conditions are different from expectations such that changes must be made to the SAP once the samplers are in the field. The following paragraph provides a means for documenting those deviations, or variances. Adopt the paragraph as is, or modify it to project-specific conditions.]

As conditions in the field may vary, it may become necessary to implement minor modifications to sampling as presented in this plan. When appropriate, the QA Office will be notified and a verbal approval will be obtained before implementing the changes. Modifications to the approved plan will be documented in the sampling project report.

12 FIELD HEALTH AND SAFETY PROCEDURES

[Describe any agency-, program- or project-specific health and safety procedures that must be followed in the field, including safety equipment and clothing that may be required, explanation of potential hazards that may be encountered, and location and route to the nearest hospital or medical treatment facility. A copy of the organization health and safety plan may be included in the Appendix and referenced in this section.]