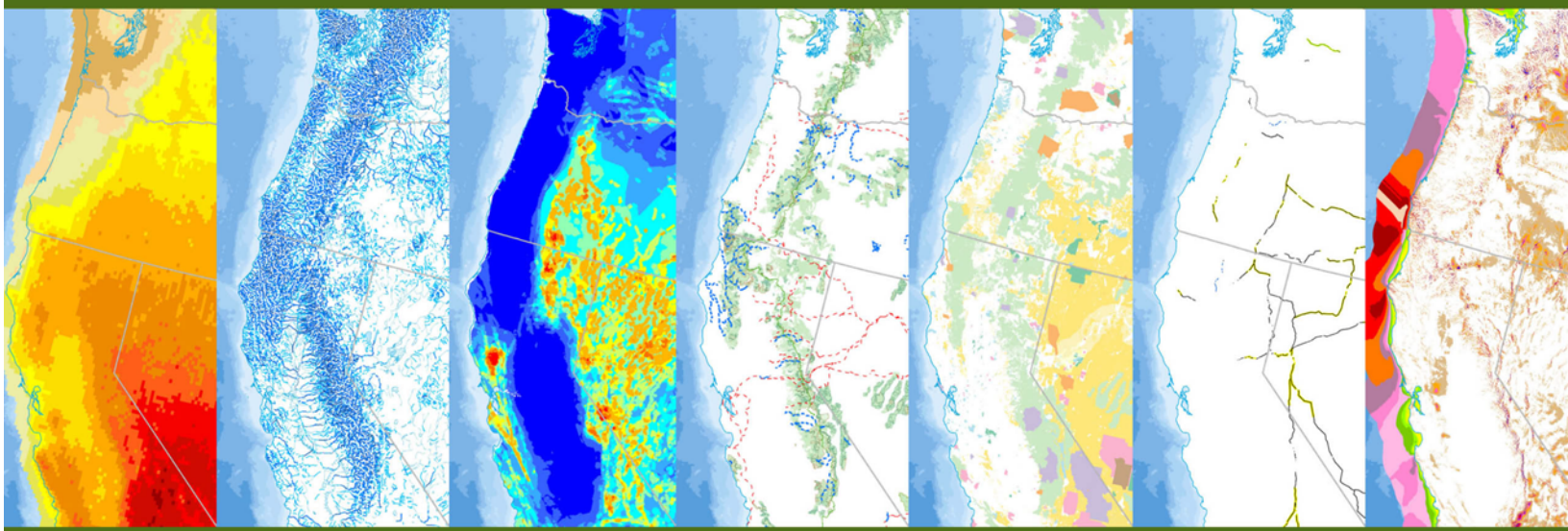


RENEWABLE ENERGY ATLAS

OF THE UNITED STATES



APRIL 2012

PREPARED BY
ARGONNE NATIONAL LABORATORY

FOR
U.S. DEPARTMENT OF AGRICULTURE – FOREST SERVICE
LANDS AND REALTY MANAGEMENT
WASHINGTON, D.C.



U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

About Argonne National Laboratory

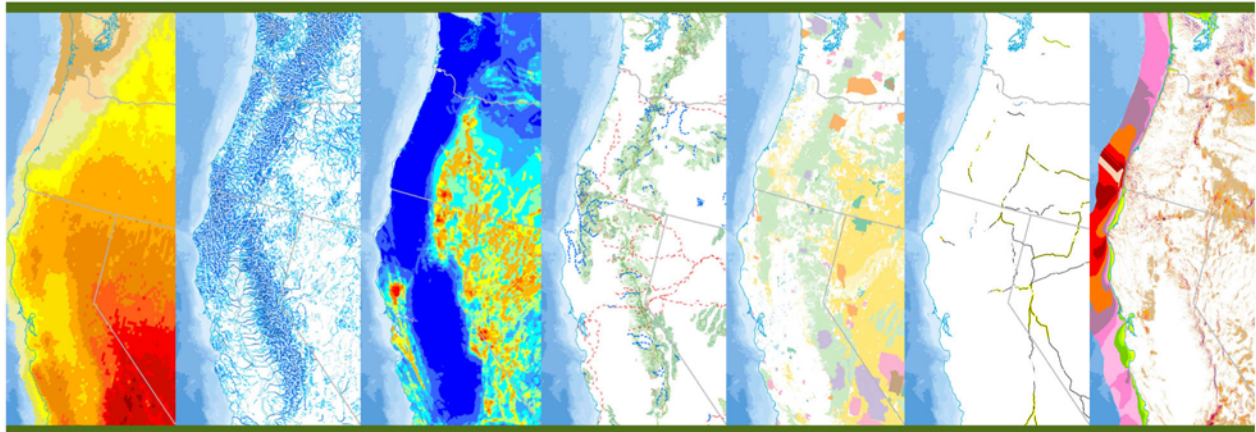
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RENEWABLE ENERGY ATLAS

OF THE UNITED STATES



APRIL 2012

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1. INTRODUCTION

The Renewable Energy Atlas (Atlas) of the United States is a compilation of geospatial data focused on renewable energy resources, federal land ownership, and base map reference information. It is designed for the U.S. Department of Agriculture Forest Service (USFS) and other federal land management agencies to evaluate existing and proposed renewable energy projects.

Much of the content of the Atlas was compiled at Argonne National Laboratory (Argonne) to support recent and current energy-related Environmental Impact Statements and studies, including the following projects:

- West-wide Energy Corridor Programmatic Environmental Impact Statement (PEIS) (BLM 2008),
- Draft PEIS for Solar Energy Development in Six Southwestern States (DOE/BLM 2010),
- Supplement to the Draft PEIS for Solar Energy Development in Six Southwestern States (DOE/BLM 2011),
- Upper Great Plains Wind Energy PEIS (WAPA/USFWS 2012, in progress), and
- Energy Transport Corridors: The Potential Role of Federal Lands in States Identified by the Energy Policy Act of 2005, Section 368(b) (in progress).

This report explains how to add the Atlas to your computer and install the associated software; describes each of the components of the Atlas; lists the Geographic Information System (GIS) database content and sources; and provides a brief introduction to the major renewable energy technologies.

2. CONTENT OF THE ATLAS

The Atlas includes the following components:

- A GIS database organized as a set of Environmental Systems Research Institute (ESRI) ArcGIS Personal GeoDatabases,
- ESRI ArcReader and ArcGIS project files providing an interactive map visualization and analysis interface, and
- A Keyhole Markup Language (KML) file, compatible with Google Earth and other applications, that presents renewable energy resources, installed projects, and fact sheets in a dynamic interface.

3. INSTALLING ARCREADER AND NAVIGATING THE ATLAS

ESRI ArcReader 9.3, ArcGIS ArcView 9.3, or a more current version of either product is required to open the interactive map project files. ArcReader is a free application distributed by ESRI, and ArcView is a commercial product with more extensive capabilities. The instructions below assume ArcReader is being used. (When using ArcView, open the mxd files rather than the pmf files.) Because of the size and

complexity of the database, ArcReader or ArcView may take a few minutes to open the interactive map project file on some computers.

- 1) Download ArcReader 9.3 (or a more current version) from <http://www.esri.com/software/arcgis/arcreader/download.html>.
- 2) Extract the contents of the downloaded zip file, run the ESRI.exe installation program with an administrator account, and install the software.
- 3) For better performance, copy the files to a local hard disk on your system.
- 4) Double-click the Atlas folder and then double-click on the Renewable_Energy_Atlas.pmf file to open the Atlas in ArcReader (or the Renewable_Energy_Atlas.mxd file if using ArcView). The Atlas folder also has project files for each USFS region, Alaska, and Hawaii. Figure 3-1 shows a view of the Atlas in ArcReader.
- 5) If you are not familiar with ArcReader, start by choosing the **Help → ArcReader Help** menu item for a guide on getting started with the software.

Below are some important considerations that will help improve your use of the Atlas:

- Due to the many map layers in the Atlas there will be cases when one map layer obscures another one of interest. Layers in the map are drawn in reverse of the order in which they appear in the table of contents. In ArcView, drag a layer in the table of contents higher than a layer obscuring it to make it draw above the other one. ArcReader does not provide this capability; however, the **Transparency** and **Swipe Layer** tools provide ways to view layers that might otherwise be obscured.
- Some layers have detailed information that takes a long time to display when the map is zoomed out. Scale dependency (a property where layers are only displayed at specified scale ranges) was avoided in ArcReader because the dependency cannot be changed by users. If a map display is taking too long to draw, press the **Escape (Esc)** key to stop the drawing process, then turn the layer off in the **Table of Contents** or **Zoom** the map into a smaller area.
- The Atlas is organized in three geographic areas to minimize map distortion: Contiguous United States, Alaska, and Hawaii. To switch between the regions, double-click on the region name in the **Table of Contents**. Separate project files focus exclusively on each USFS region, Alaska, and Hawaii.
- Most GIS layers include useful information beyond the field used to symbolize the map. For example, the Photovoltaic Potential layer in the Solar Resources Group is symbolized by annual average global horizontal irradiance (GHI); however, the tabular data for this layer also includes monthly averages. In ArcReader, use the Information tool to access this information. In ArcView, right-click on a layer name in the **Table of Contents** and choose **Open Attribute Table**.
- The Gauging Stations layer in the Hydrography Group links to live Web-based flow data from the USGS. When the layer is displayed on the map, click on a station with the **Hyperlinks** tool to open a Web page with the flow data for that station. The Web data can also be accessed by clicking on

a gauging station with the **Information** tool, then clicking on the URL listed in the information tool dialog output.

- The Road Atlas, Topographic, and Image Base Map layers at the bottom of the table of contents are Internet-based map services provided by ESRI. They require an adequate Internet connection to work properly, and provide high-quality base maps at both general and detailed scales.

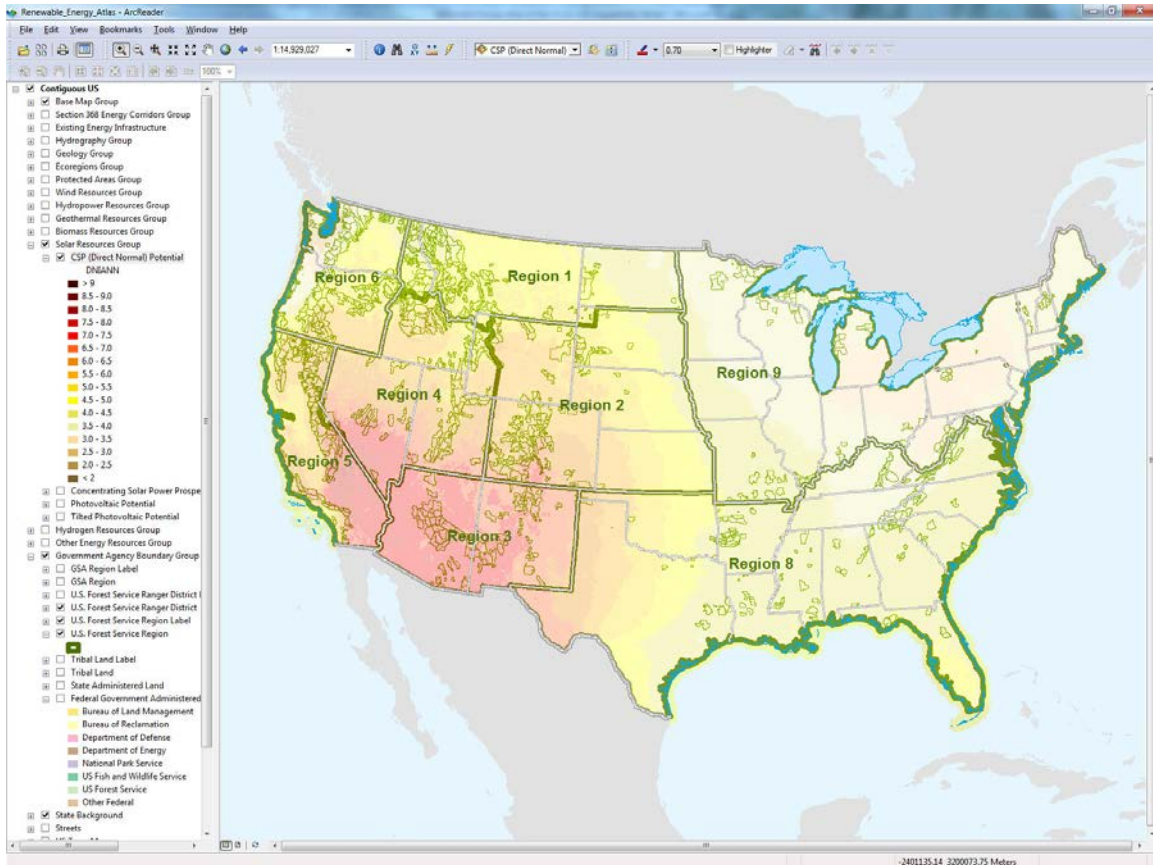


Figure 3-1 View of the Renewable Energy Atlas in ArcReader with Concentrating Solar Potential and USFS Forests and Regions

4. GIS DATABASE CONTENT

The Atlas contains a large inventory of renewable resource, federal land, and base map information that can be accessed and superimposed in many combinations. Layers with similar themes are grouped together (see Figure 3-1 and Section 8). For example, Figure 4-1 shows hydrography and hydropower information for the Darrington Ranger District in Mt. Baker–Snoqualmie National Forest in Washington. The Hydrography Group in the Atlas includes hydrologic units (watersheds), as classified by the USGS; gauging stations that link to live flow data; streams; water bodies; and aquifers. There is also a Hydropower Resources Group that focuses on water as an energy resource, and the technologies that use it. Within that group, the Hydropower Resource layers categorize potential sites and reaches by the type of technology most suited to the location (INEEL 2004).

Layers included in the Existing Energy Infrastructure Group are quite limited, despite their applicability to the Atlas, because the best available energy infrastructure data is either commercially licensed or designated Official Use Only. We recommend that users requiring this information obtain it from the data sources described below, or other sources.

For pipeline information, the National Pipeline Management System (DOT 2012) provides coverage of the contiguous 48 states. Federal, state, and local governments, and pipeline operators, can request a copy of the GIS data from the U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration. Instructions for the data request are available at <http://www.npms.phmsa.dot.gov>.

Electrical infrastructure, pipeline infrastructure, and other energy-related GIS data are available from Bentek Energy (2012), Hart Energy (2012), and several other commercial vendors.

A comprehensive listing of the GIS Database Content is provided in Section 8.

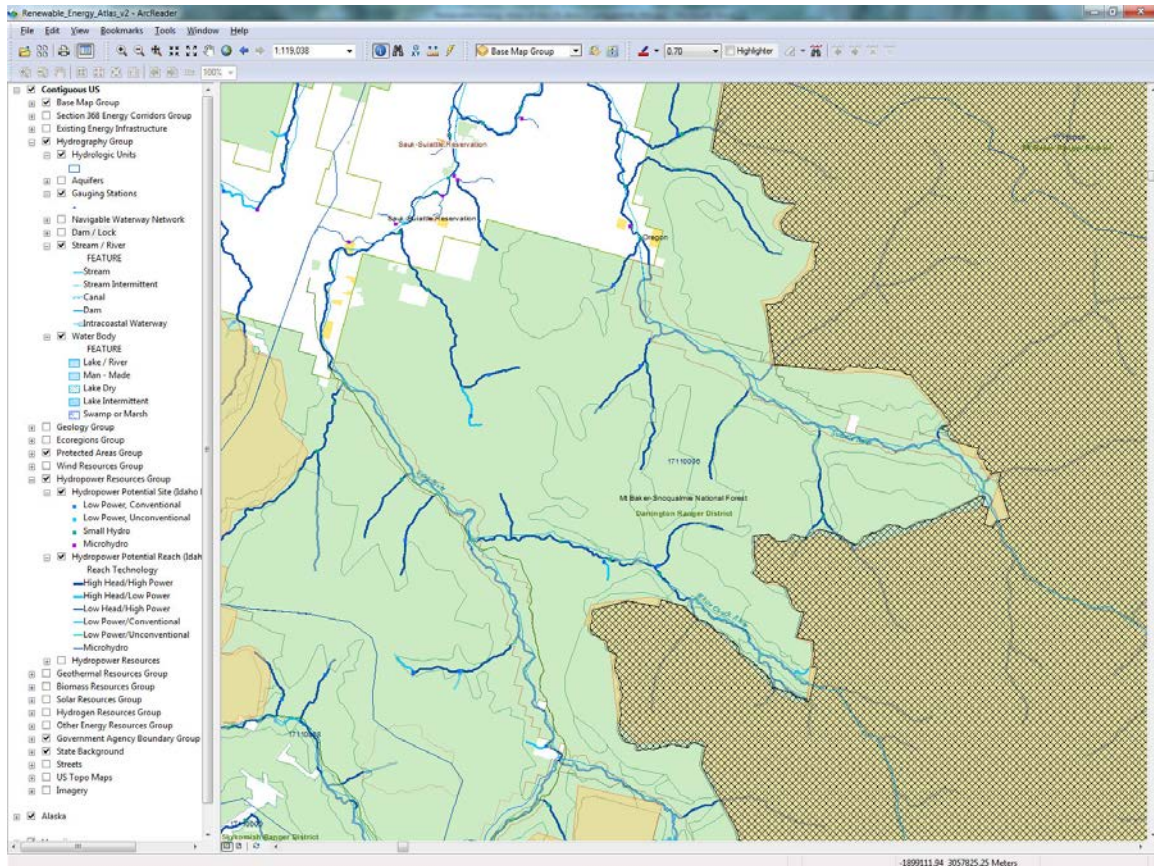


Figure 4-1 Hydrography and Hydropower Information for the Mt. Baker Snoqualmie National Forest in Washington

5. SPREADSHEET DATA CONTENT

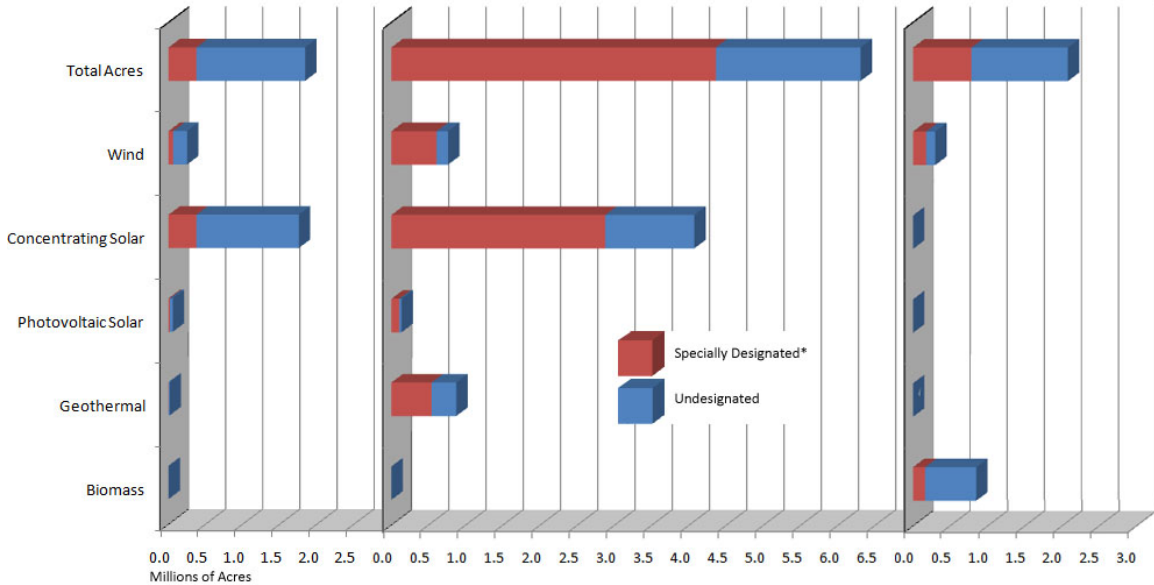
Cross tabulations of federal land jurisdictions, protected lands, and renewable energy resources have been provided as a spreadsheet, *Renewable_Energy_Atlas.xls*, in the Analysis folder. The following information is included in the spreadsheet:

- Federal land acreage by agency and state;
- USFS land acreage by state, forest, and special designation;
- USFS land acreage by state, forest, and high-quality renewable resource category (including wind, concentrating solar, photovoltaic solar, geothermal, biomass, and hydrokinetic);
- USFS potential for high-quality resource acreage;
- U.S. Fish and Wildlife Service (USFWS) land acreage by state, refuge, and high-quality renewable resource category (including wind, concentrating solar, photovoltaic solar, geothermal, biomass, and hydrokinetic);
- U.S. Department of Energy (DOE) land acreage by state, property, and high-quality renewable resource category (including wind, concentrating solar, photovoltaic solar, geothermal, biomass, and hydrokinetic);
- U.S. National Park Service (NPS) land acreage by state, park, and high-quality renewable resource category (including wind, concentrating solar, photovoltaic solar, geothermal, biomass, and hydrokinetic);
- U.S. Department of Defense (DOD) land acreage by state, installation, and high-quality renewable resource category (including wind, concentrating solar, photovoltaic solar, geothermal, biomass, and hydrokinetic); and
- U.S. Bureau of Land Management (BLM) land acreage by state, district, and high-quality renewable resource category (including wind, concentrating solar, photovoltaic solar, geothermal, biomass, and hydrokinetic).

Figure 5-1 shows some of the information provided in the spreadsheet in graphical form. Several national forests were selected based on their unique mix of specially designated lands and renewable resources.

6. KEYHOLE MARKUP LANGUAGE (KML/KMZ) FILE CONTENT

Renewable energy resource layers, existing project locations, and fact sheets are combined in the *Renewable_Energy_Atlas_v1.5.kmz* file, found in the KML folder, which can be opened in Google Earth (Google 2012), National Aeronautics and Space Administration (NASA) World Wind (NASA 2012), or other software. Both Google Earth and NASA World Wind provide detailed and current imagery base maps and other map overlays. The contents of the KMZ file can be interactively superimposed within an easy-to-use, globe-based interface. Links in the fact sheets connect to additional figures and information available on the Internet. The KML/KMZ project file is large and some of the layers will take a few moments to display. Figures 6-1 and 6-2 show example views of the KML file content in Google Earth.



*Specially designated lands include roadless, wilderness, wilderness study, and national monument areas within the National Forest boundaries. Viable locations for siting renewable energy projects depend on many additional siting factors.

Figure 5-1 Comparison of Total vs. Specially Designated Acreages and High-quality Renewable Resource Categories for Cibola, Humboldt-Toiyabe, and Shasta-Trinity National Forests



Figure 6-1 Google Earth View of Wind Resource Data for the Northern Plains States and a Fact Sheet about the Chanarambie Wind Energy Facility



Figure 6-2 Perspective View of Nevada Solar One Power Plant and Associated Fact Sheet in Google Earth

7. RENEWABLE ENERGY TECHNOLOGIES

This section briefly describes the major renewable energy technologies with examples of installed projects. This content is also included in the KML file and can be viewed interactively in a geographic context in Google Earth, NASA World Wind, and other applications that support KML.

7.1 SOLAR POWER

Solar collectors can be used to harness solar energy—the light and heat radiated from the sun—to produce electricity. There are two general categories of solar technologies: concentrating solar power (CSP) and photovoltaic (PV). CSP technologies use reflective surfaces (usually mirrors) to concentrate the sun’s energy to produce heat. The heat then drives either a steam turbine or an external heat engine to produce electricity. Linear concentrator, power tower, and dish engine technologies fall into the CSP category. In PV technologies, the photons in sunlight are converted directly to electricity.

7.1.1 LINEAR CONCENTRATORS

Linear concentrator systems use mirrors that focus solar energy on receiver tubes containing a heat transfer fluid. The fluid in the receiver tubes is heated by the solar energy and is used to create superheated steam, which spins turbines that run a generator to create electricity. The major components of typical utility-scale linear concentrator facility are the solar field, the power block, and the cooling system. The solar field consists of long rows of solar collectors (100 to 150 ft) that typically track the sun from east to west each day. There are two types of linear concentrator systems: parabolic trough systems (more common) and Fresnel reflector systems. In the parabolic trough systems, fluid is heated in the

receiver tube that is the focal line in a parabola-shaped mirror (Figure 7.1-1). The linear Fresnel reflector system uses flat mirrors that are cheaper to produce and water is heated directly in the receiver tubes (Figure 7.1-2). Parabolic trough facilities may include thermal energy storage capability, whereby excess heat generated is stored in a thermal storage medium (typically molten salt), then used during non-sunlight hours.

To learn more about linear concentrator technology visit http://www.eere.energy.gov/basics/renewable_energy/linear_concentrator.html. Specific information about parabolic trough technology can be found at <http://www.nrel.gov/csp/troughnet>.

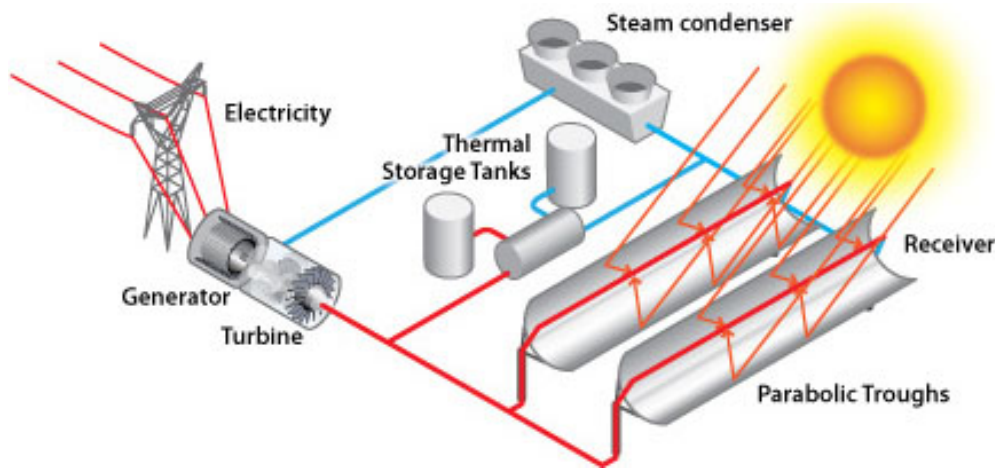


Figure 7.1-1 Concentrating Solar Power Systems: Parabolic Trough Systems (DOE 2010a)

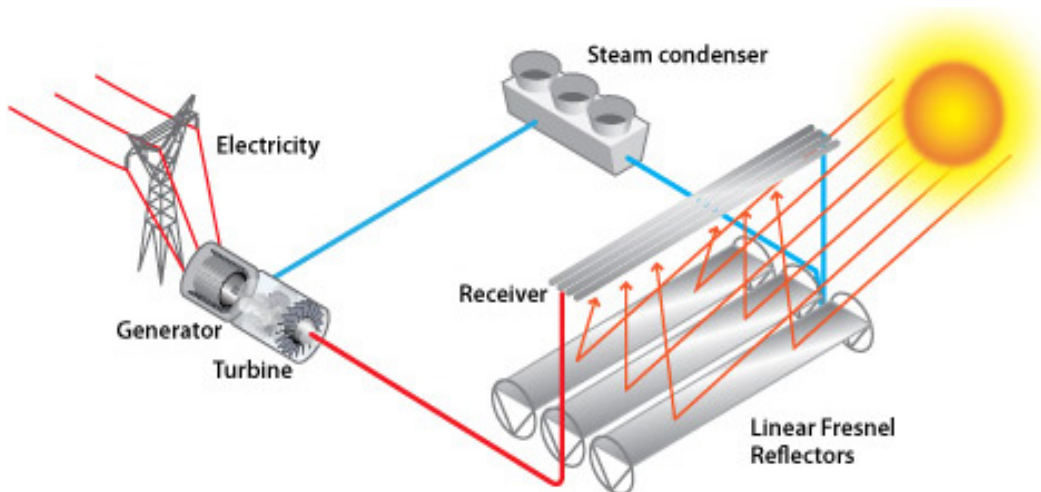


Figure 7.1-2 Concentrating Solar Power Systems: Linear Fresnel Reflector System (DOE 2010b)

Example Solar Linear Concentrator Project

The Nevada Solar One project encompasses 400 acres and has a power capacity of 75 MW (Figure 7.1-3). This system consists of 760 parabolic troughs with 182,000 mirrors and 18,240 receiver tubes, each 4 m in length.



Figure 7.1-3 Nevada Solar One Parabolic Trough Facility (NREL 2007a)

7.1.2 SOLAR POWER TOWER

Utility-scale power tower facilities consist of hundreds or thousands of flat mirrors (called heliostats) that direct solar energy towards a central tower (Figure 7.1-4). The heliostats are equipped with systems that track the sun from east to west to maximize power capture. The typical height of a solar power tower is about 300 to 450 ft. The heliostats concentrate the solar energy on a central point at the top of the tower, where a heat transfer fluid (HTF) absorbs the heat. Then the HTF is used to create superheated steam, which spins turbines that run a generator to create electricity. Water has been used in the past as a HTF in power tower facilities; however, molten salts are now being used as HTFs, because they have thermal

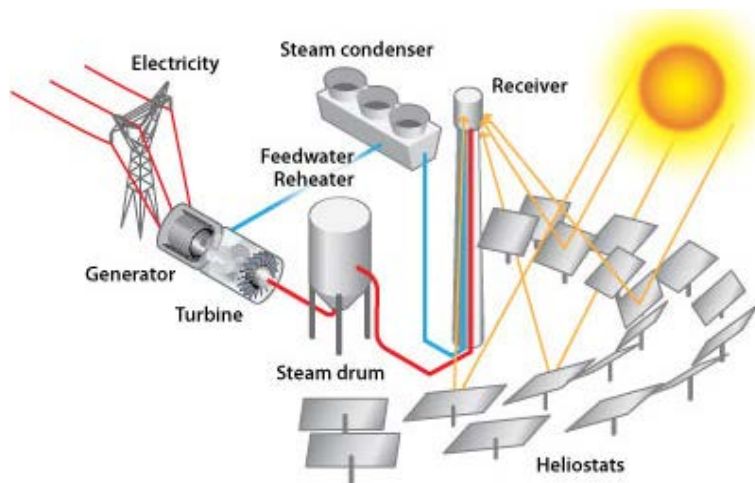


Figure 7.1-4 Concentrating Solar Power Systems: Power Tower System (DOE 2010c)

energy storage capabilities. The major components of a typical utility-scale power tower facility are the solar field, tower, power block, and cooling system. Power tower facilities may include thermal energy storage capability, whereby excess heat generated is stored in a thermal storage medium (typically molten salt) and used during non-sunlight hours.

To learn more about solar power tower technology visit http://www.eere.energy.gov/basics/renewable_energy/power_tower.html.

Example Solar Power Tower System

Sierra Sun Tower is a demonstration facility located outside of Lancaster, California, encompassing 20 acres and operated by eSolar (Figure 7.1-5). The eSolar system is modular, using multiple 180-ft-tall power towers, each with a set of 12,000 heliostats. Each module generates 2.5 MW of power, and the Lancaster facility has two modules with a capability of generating 5 MW of power.



Figure 7.1-5 eSolar's Sierra SunTower Facility outside of Lancaster, California (NREL 2010b)

7.1.3 SOLAR DISH ENGINE SYSTEMS

Solar dish engine systems are stand-alone CSP energy generation systems that can generate from 3 to 50 kW each. A typical dish system consists of a parabola-shaped concentrator, a receiver, an external heat engine, and a generator (see Figure 7.1-6). Sunlight is concentrated onto the receiver, which transfers the heat to a gas (usually hydrogen or helium) contained in the sealed external heat engine. As the gas is heated, its increasing pressure drives a piston within the engine, thus powering the generator and producing electricity. Cooling occurs within the engine on the side that faces away from the concentrator, so no cooling water is required. A sun tracking system, powered by the dish engine unit, is used to maximize sun concentration throughout the day. Individual dish engines can be grouped together into facilities with widely varying power capacities.

To learn more about dish engine technology visit http://www.eere.energy.gov/basics/renewable_energy/dish_engine.html.

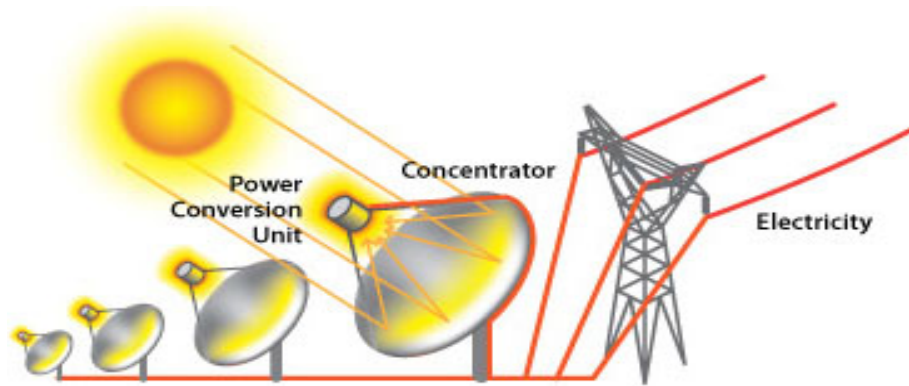


Figure 7.1-6 Concentrating Solar Power Systems: Dish/Engine System (DOE 2010d)

Example Solar Dish Engine System

The Maricopa Solar Power Plant in Peoria, Arizona, uses 60 SunCatcher dish engines, each with a 25-kW capacity (Figure 7.1-7). Each dish is 38 ft in diameter and automatically tracks the sun throughout the day. The 1.5-MW system extends over 15 acres and began operating in January 2010.



Figure 7.1-7 SunCatcher Solar Dish Engines at the Maricopa Solar Power Plant (NREL 2010c)

7.1.4 PHOTOVOLTAIC SYSTEMS

PV cells, also known as solar cells, are primarily made up of semiconductor material that absorbs the energy of sunlight and transforms it into electrical energy. The semiconductor material can be made of silicon, polycrystalline thin films, or single-crystalline thin films. To produce electricity at the utility scale, many individual solar cells are connected into a module; modules are combined to make individual solar panels; and solar panels are grouped into arrays that produce direct current (DC) electricity (Figure 7.1-8). The modular nature of PV systems allows great flexibility in sizing facilities to accommodate factors such as the amount of power needed or the amount of land area available. There are two types of PV systems: flat plate, and PV concentrator systems. PV concentrator systems use reflective material to concentrate

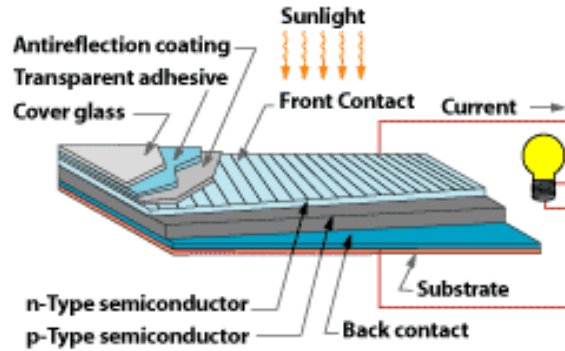


Figure 7.1-8 Diagram of a Photovoltaic Cell (DOE 2010e)

the sun’s energy onto smaller areas, which results in a reduced need for solar cell material compared to flat plate systems that generate the same amount of electricity. Solar cell efficiency is increased in PV concentrator systems; their expensive optics, the added cost of sun tracking systems, and excess heat are disadvantages.

To learn more about PV technology visit

http://www.eere.energy.gov/basics/renewable_energy/photovoltaics.html.

Example Solar Photovoltaic Systems

The DeSoto Next Generation Solar Energy Center is located in DeSoto County, Florida, and has the capacity to generate 25 MW. The facility has over 90,000 solar panels on 180 acres of land. These solar panels are equipped with single-axis trackers, which increase energy production throughout the day.

The Nellis Air Force Base Solar Power System is a PV facility located in Las Vegas, Nevada, that has a generation capacity of 14.2 MW (Figure 7.1-9). The Nellis facility spans over 140 acres and is equipped with 72,416 solar panels, each of which generates 200 W. A SunPower Tracker system made up of 5,821 units is used to maximize generation capability throughout the day.



Figure 7.1-9 Photovoltaic Solar Power System at Nellis Air Force Base (NREL 2007b)

7.2 WIND ENERGY

Wind energy is the movement of air in the earth's atmosphere relative to a fixed point on the earth's surface. The air movement is primarily caused by the uneven heating of the earth's surface by solar radiation. The spinning motion of wind turbine blades is used to convert kinetic wind energy to mechanical energy, and a generator converts the mechanical energy to electricity. The electricity can then be tied into the utility grid (Figure 7.2-1).

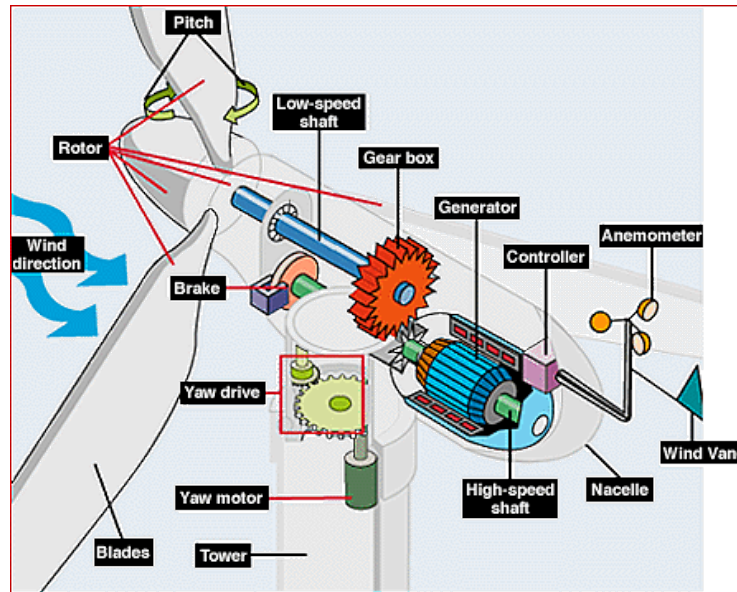


Figure 7.2-1 Inside a Wind Turbine System (DOE 2010f)

There are two major types of wind turbines: horizontal axis and vertical axis. Horizontal axis wind turbines are the predominant technology used in commercial wind farms. Commercial utility wind turbines can generate anywhere from 100 kW to several megawatts of electricity. Some smaller scale wind turbines (100 kW or lower) are used by individuals and businesses. One of the cheapest forms of renewable energy is wind technology, which can cost between 5 and 8 cents per kilowatt-hour. In addition, wind turbines can be erected on ranches and farms with minimal or no change to agricultural uses. The main disadvantages of wind power include the following:

- It can be an intermittent resource, and a backup source of energy may be needed for utility-scale facilities;
- Wind resources are concentrated in remote areas, making transmission lines connecting remote areas to population centers essential;
- Wind turbines can produce considerable noise;
- Some people dislike the aesthetics of wind turbines in their landscapes; and
- Wind turbines may potentially harm wildlife (e.g., birds and bats).

To learn more about wind energy technology visit

http://www.eere.energy.gov/basics/renewable_energy/wind.html.

Example Wind Energy Projects

The Horse Hollow Wind Energy Center, located on 47,000 acres of land in Taylor and Nolan Counties, Texas, has the capacity to generate 735 MW of electricity. The facility consists of 291 1.5-MW wind turbines and 130 2.3-MW wind turbines.

The Foote Creek Rim Project, near Arlington, Wyoming, sits on top of a treeless plateau in one the windiest places in the United States (Figure 7.2-2). Foote Creek Rim was the first commercial wind energy facility in Wyoming and can operate with 8 to 65 mph winds. The facility currently has 183 turbines and a generating capacity of 134.7 MW.



Figure 7.2-2 Wind Turbines at the Foote Creek Rim Project near Arlington, Wyoming (NREL 1998)

7.3 GEOTHERMAL ENERGY

Geothermal energy originates from the naturally occurring heat of the earth's interior. The heat energy can be retrieved by drilling water or steam wells, or it can be found directly on the surface of the earth in the form of steam vents, geysers, mud pots, and hot springs. Heat resources found deeper than a mile below the earth's surface are termed geothermal reservoirs, and wells can be drilled to access their steam and very hot water. The steam and hot water can then be used by a geothermal power plant to spin turbines that, in turn, drive generators, creating electricity. In addition to power plants, geothermal energy can be harnessed through direct use and geothermal heat pump systems. Direct use of geothermal fluids involves piping hot water directly into buildings or other facilities for heating purposes. Geothermal heat pump systems use the stable temperatures of the upper 10 ft of the earth's surface to heat and cool buildings by circulating water through the shallow ground and employing a heat exchanger system.

Three types of technologies are used for geothermal power plants: dry steam, flash steam, and binary cycle. All three geothermal power plant types recycle the hot water and inject the remaining geothermal fluid back into the reservoir. In addition, geothermal power plants require a cooling system that prevents turbines from overheating, which ultimately extends the life of the facility. In dry steam plants, the steam is used directly to spin turbines that drive a generator to create electricity (Figure 7.3-1). In flash steam plants, steam or water under high temperatures and/or pressures is put into a tank at lower pressure, thereby flashing the vapor (Figure 7.3-2). The flashed vapor is used to spin turbines that drive an electrical

generator. In a binary cycle plant, the temperature of the extracted geothermal fluids is usually lower than the boiling point (see Figure 7.3-3). A fluid with a lower boiling point than water is then heated by the geothermal fluids, and the flash of the binary fluid is used to spin the turbines.

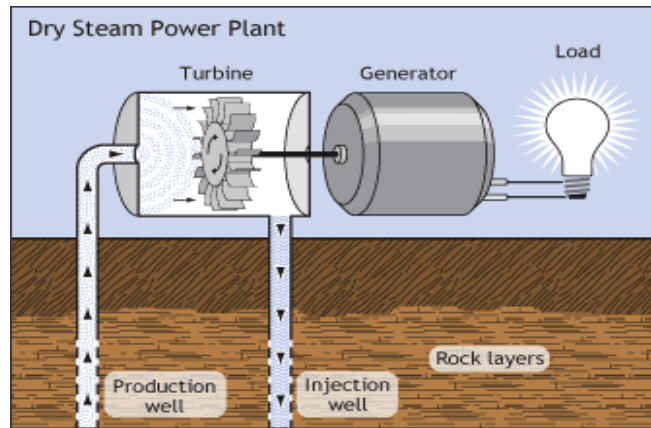


Figure 7.3-1 Dry Steam Geothermal Power Plant (DOE 2010g)

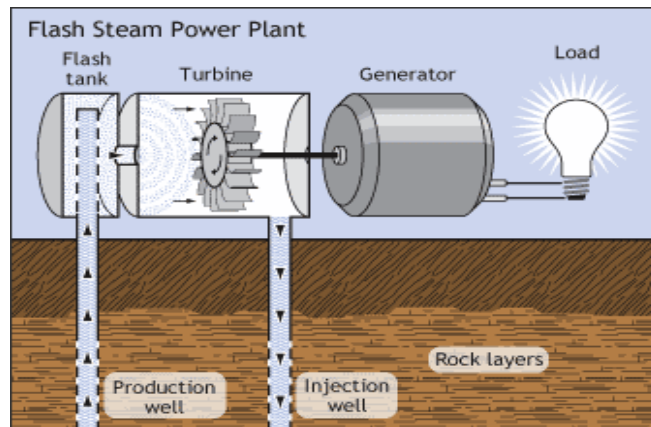


Figure 7.3-2 Flash Steam Geothermal Power Plant (DOE 2010h)

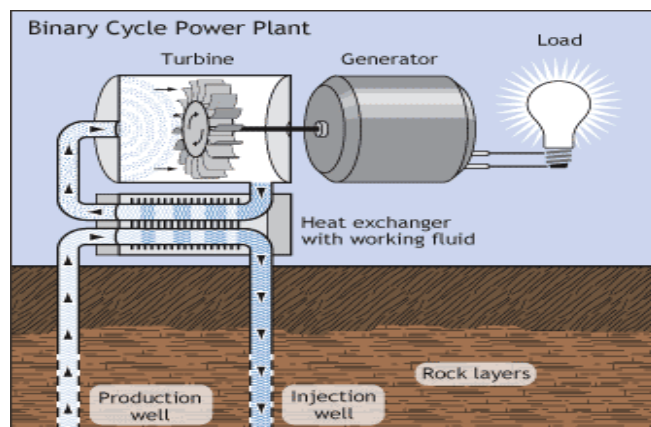


Figure 7.3-3 Binary Cycle Geothermal Power Plant (DOE 2010i)

To learn more about geothermal energy technology visit http://www.eere.energy.gov/basics/renewable_energy/geothermal.html.

Example Geothermal Energy Projects

The Geysers, located in northern California near Healdsburg, includes 22 individual dry steam power plants that utilize steam from over 350 wells on 8,095 acres of land (Figure 7.3-4). The Geysers has the capacity to generate 1517 MW of electricity and is the largest dry steam power plant in the United States. Approximately 250 MW of energy are generated at The Geysers on land leased from the Federal Government.



Figure 7.3-4 One of 22 Geothermal Energy Plants at the Geysers (NREL 2010a)

Puna Geothermal Venture, located in Puna on the Big Island of Hawaii, uses binary cycle technology to spin steam turbine generators to generate up to 30 MW of energy. The facility is situated on 30 acres of land within the Kilauea East Rift Zone. The electricity generated at Puna Geothermal Venture is sold to Hawaiian Electric Light Company, which distributes the energy to various customers.

7.4 ENERGY FROM BIOMASS

Biomass is living, or once living, matter including plants and animals. Plants harness carbon dioxide from the surrounding environment to create energy from the sun through photosynthesis. When animals consume plant material, the chemical energy found in plants is transferred to the animal. The energy found in plants and animals remains until they start to decompose or are altered by processes such as burning. Forms of plant matter and animal matter used to produce energy include crop residue, forest residue, manure, sanitary wastewater, animal waste from slaughterhouses, grease from restaurants, and landfill waste (Figure 7.4-1). Some crops are grown for the specific purpose of being used for energy production and are termed “dedicated energy crops.”

Dedicated energy crops can be used directly as fuel or processed for use in biofuel applications. Agricultural crops used for biofuel fall within two categories: crop biomass used to make biofuels, and crops raised for oily seeds that can be converted to biodiesel. Corn, sugarcane, and switchgrass are crops that are currently being used to make biofuels. Soybeans, sunflowers, rapeseed, and castor beans are some of the oily seeds used to create biodiesel. Research is being conducted on the use of algae for energy because algae mass grows quickly and includes lipids and triglycerides that are also found in

vegetable oils. The primary woody crops include trees (e.g., hybrid willow and hybrid poplar trees) that are grown in forest plantations for the sole purpose of generating heat and energy.

A conversion process is needed to turn woody plants, agricultural crops, or waste into biofuels. There are two general types of conversion processes: biochemical conversion, and thermochemical conversion. The biochemical conversion process has five steps: (1) biomass is pretreated with heat, water, acid, or bases to break down the biomass into sugars and make the cellulose more accessible; (2) the carbohydrates are separated and the sugar is released (hydrolysis); (3) the sugar is separated and cleaned to increase the efficiency and purity of the biomass (cleanup/separation); (4) organisms are added to ferment the sugar to carbon dioxide and alcohol; and (5) the fermented material is distilled to separate the ethanol/alcohol from water and other solid matter. The solid matter can be than burned to produce heat or create energy, or go through the thermochemical process to be used as fuel additives.

Thermochemical conversion is a four-step process: (1) biomass is broken down to a synthesis gas (gasification) and is oxidized with air, oxygen, or steam; (2) contaminants (e.g. tars, acid gas, alkali metals, and other particles) are removed and the gas is conditioned until it has the correct hydrogen-carbon monoxide ratio (gas cleanup and conditioning); (3) the feedstock is heated with no oxygen, which breaks the product down into oil (pyrolysis); and (4) the oil is cleaned and processed into different hydrocarbon fuels by reducing the oil's oxygen content (bio-oil cleanup).

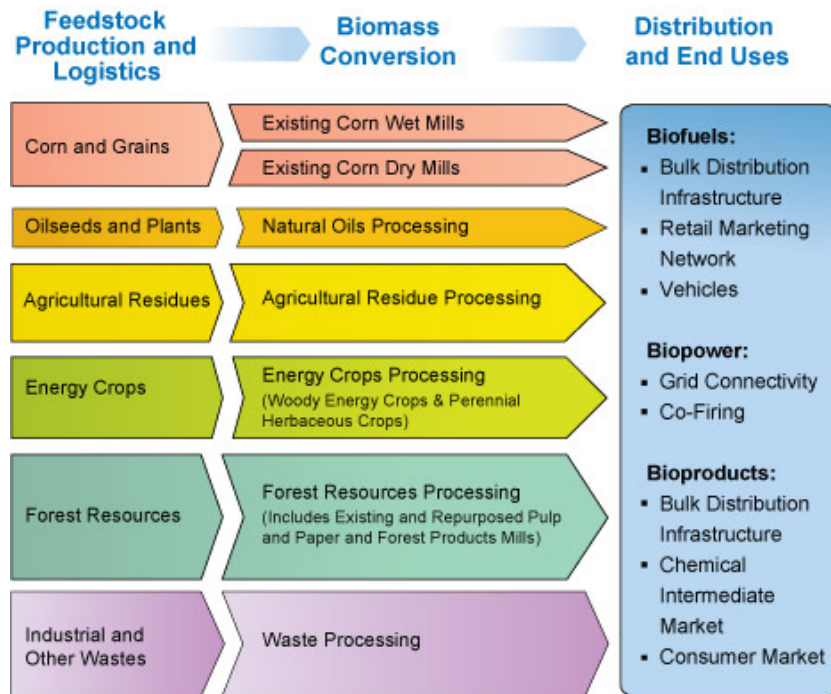


Figure 7.4-1 Forms of Biomass That Can Be Converted to Energy (DOE 2010j)

To learn more about energy from biomass, visit http://www.eere.energy.gov/basics/renewable_energy/biomass.html, <http://www.epa.gov/lmop>, and <http://glbrc.org>.

To learn the locations of current biorefineries in the United States visit http://www1.eere.energy.gov/biomass/integrated_biorefineries.html.

Example Biomass Energy Projects

Farms in the Emmetsburg, Iowa, area are using crop residues and corncobs to generate cellulosic biofuels (ethanol) using a biorefining process.

Methane from the Puente Hills Landfill in Whittier, California, is converted into electricity using a steam turbine system. The plant has the capacity to generate 50 MW of electricity.

The King County South Treatment Plant, of Renton, Washington, generates combined heat and power (CHP) using a molten carbonate fuel cell to generate up to 1 MW of electricity from methane derived from wastewater.

The Biofuels Center of North Carolina, in Oxford, North Carolina, conducts research on using forest residues and mill residues, and studies tree species suitable for conversion into biofuels.

The Michigan State University Forest Biomass Innovation Center, in Escanaba, Michigan, researches and develops ways to make fuels from cellulose using dedicated energy crops.

7.5 HYDROPOWER

The energy in moving water can be converted to electric power (hydropower) using turbine systems, or the energy can be used directly to power machinery. The amount of energy in water is determined by its fall (potential energy) or velocity (kinetic energy). “Hydropower remains the largest source of renewable energy generation, and an important component of the energy mix; primarily large-scale hydropower accounts for 6.2% of U.S. electricity generation” (DOE 2011). In conventional hydropower systems, river water is stored behind a dam and is released through a penstock that transmits the water to turbines that spin generators to create electricity. Conventional hydropower systems utilize the fall of water to create electricity from the potential energy of the water stored behind the dam (Figure 7.5-1). Run-of-the-river systems also use the fall of water to create electricity, but do not store a large reservoir of water behind a dam (Figure 7.5-2). In these systems, some or all of the river water is diverted through a penstock and into turbines to generate electricity (Figure 7.5-3), then returned to the river downstream. Small hydro (<10 MW generating capacity) and micro hydro (<100 kW) projects can provide power on smaller rivers and to isolated areas, usually at a relatively low cost. Small and micro hydro power projects include those that extract kinetic energy from flowing water, such as tidal energy or hydrokinetic river energy (Figure 7.5-4). Hydrokinetic and tidal power systems use turbines to extract energy from the velocity of flowing water, similar to the way wind turbines extract energy from the velocity of the air. Other forms of water power that are currently under development include tidal stream power, wave power, and marine current power.

To learn more about hydropower visit <http://hydropower.inel.gov/index.shtml>, and http://www.eere.energy.gov/basics/renewable_energy/hydropower.html.

Example Hydropower Projects

Hoover Dam is located on the Colorado River near Boulder City, Nevada (Figure 7.5-1). One of the country's largest conventional hydropower plants, Hoover Dam has the capacity to generate 2,080 MW of electricity and has been operating since 1936.



Figure 7.5-1 Hoover Dam, a Conventional Hydropower Plant (USBR 2007)

Chief Joseph Dam is a run-of-the-river hydropower project located on the Columbia River near Bridgeport, Washington (Figure 7.5-2). The plant has been operational since 1958 and its current energy generating capacity is 2,620 MW.



Figure 7.5-2 Chief Joseph Dam a Run-of-the-River Hydropower Plant (USACE 2010a)

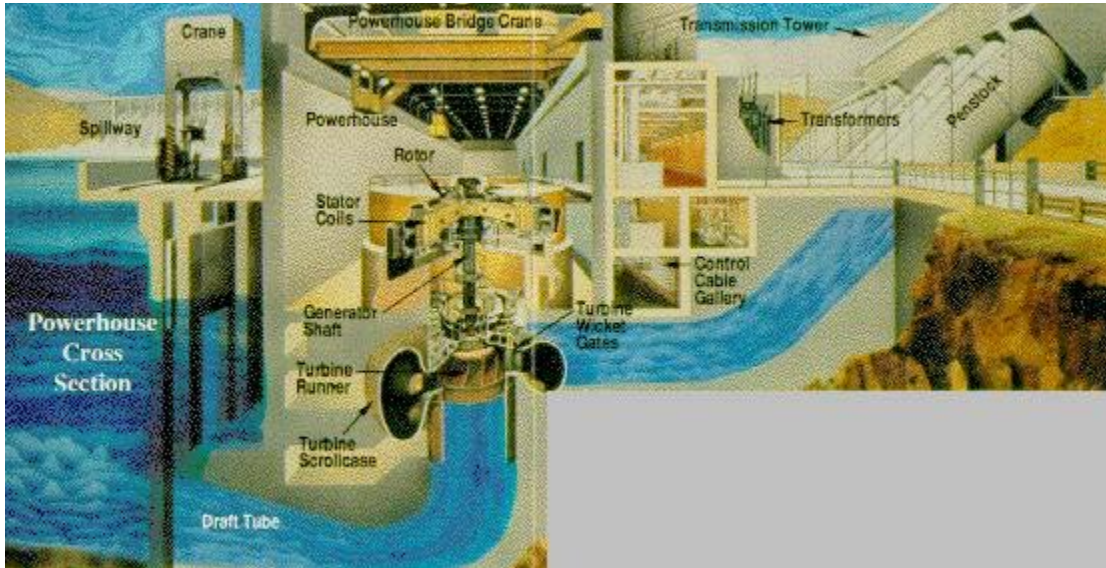


Figure 7.5-3 How Chief Joseph Dam's Run-of-the-River System Works (USACE 2010b)

Operations at the nation's first hydrokinetic power station began in 2009 on the Mississippi River at the U.S. Army Corps of Engineer's Lock and Dam No. 2 near Hastings, Minnesota. At full build-out, the generating capacity is anticipated to be 250 kW.



Figure 7.5-4 Mississippi River Hydrokinetic Energy at U.S. Army Corps of Engineer's Lock and Dam No. 2, Hastings, Minnesota (USACE 2012)

Tidal and Current Energy hydropower technologies are generally at early stages of planning and development. The Ruby (ABS) Alaskan Demonstration Site, in Ruby, Alaska, is at full deployment and has a generating capacity of 5 kW.

8. GIS DATABASE INVENTORY

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Base Map	County Boundary	X	X		boundary	boundary.mdb	jurisdiction_county_line	ORNL
Base Map	County Label	X	X	X	boundary	boundary.mdb	jurisdiction_county_area	National Atlas of the United States
Base Map	Elevation Contour (1,000 ft)		X		landform	landform.mdb	elevation_contour_line	ASGDC
Base Map	Elevation Contour (1,000 ft)			X	landform	landform.mdb	elevation_contour_line	Hawaii Statewide GIS Program
Base Map	Land Use/Land Cover			X	land_status	land_status.mdb	land_use_area	Hawaii Statewide GIS Program
Base Map	Major City	X	X	X	demographics	demographics.mdb	census_site_cities	US DOT
Base Map	Non-U.S. Country	X	X		boundary	boundary.mdb	jurisdiction_country_area	ESRI
Base Map	State Background	X	X	X	boundary	boundary.mdb	jurisdiction_state_area	ESRI
Base Map	Transportation Infrastructure/Airport	X	X	X	transportation	transportation_airports.mdb	airport_polygons	ESRI
Base Map	Transportation Infrastructure/Hazardous Material Route	X	X	X	transportation	transportation_railroads.mdb	railroad_centerline	BTS
Base Map	Transportation Infrastructure/Major Road	X	X	X	transportation	transportation_roads.mdb	road_centerline_ntad_nhpn	BTS
Base Map	Transportation Infrastructure/Port	X	X	X	transportation	transportation_water.mdb	transportation_ports	BTS
Base Map	Transportation Infrastructure/Railroad	X			transportation	transportation_roads.mdb	hazardous_material_routes	BTS
Base Map	U.S. Census Tract	X	X	X	demographics	demographics.mdb	census_tracts_area	ESRI
Base Map	Urban Area	X	X	X	demographics	demographics.mdb	urban_area	ESRI
Base Map/Public Land Survey System	Section	X	X		cadastre	plss_township_section.mdb	township_section_area	BLM GeoCommunicator
Base Map/Public Land Survey System	Township	X	X		cadastre	plss_township_range.mdb	township_range_area	BLM GeoCommunicator

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Biomass Resources	Biomass Assessment (NREL) (2005)	X			flora	flora.mdb	land_vegetation_area_biomass	NREL
Biomass Resources	Forested Area		X		flora	flora.mdb	land_vegetation_area	State of Alaska Division of Forestry
Communications	FAA Ten Mile Circles	X	X	X	communications	Communications_ equipment.mdb	radar_site_10_mile_buff	NOAA
Communications	WSR-88D RADAR Line of Sight	X	X	X	communications	Communications_ equipment.mdb	radar_site_line_of_sight	NOAA
Communications	WSR-88D RADAR Location	X	X	X	communications	Communications_ equipment.mdb	radar_site	NOAA
Demographics	Historical Native American Land	X			boundary	boundary.mdb	named_area_historical_native_land	Compiled by Christy Colantoni from hardcopy supplied by Bruce Verhaaren
Demographics	Judicially Established Tribal Land	X			boundary	boundary.mdb	political_jurisdiction_area_judicial_tribal	Indian Land Areas Judicially Established in 1978. Digitized from paper map.
Ecoregions	Ecoregion (Bailey)	X	X	X	ecology	ecology.mdb	ecology_management_site_bailey	National Atlas of the United States
Ecoregions	Ecoregion (Omernik, Level 3)	X	X		ecology	ecology.mdb	ecology_management_site_omernik_level3	National Atlas of the United States
Ecoregions	The Nature Conservancy's Conservation Project	X	X	X	ecology	ecology.mdb	ecology_management_site_conservation_ project	The Nature Conservancy
Ecoregions	The Nature Conservancy's Ecoregional Portfolio	X	X	X	ecology	ecology.mdb	ecology_management_site_ecoregional_ portfolio	The Nature Conservancy
Energy Corridor	National Interest Electric Transmission Corridors	X			land_status	land_status.mdb	national_corridor_area	Argonne/DOE
Energy Corridor	Section 368 Centerline w/Designation	X			land_status	wwec.mdb	developable_area_section368_centerline_eis	Argonne

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Energy Corridor	Section 368 Centerline w/Designation	X			land_status	wwec.mdb	sec368centerline_atts	Argonne
Energy Corridor	Section 368 Centerline w/Mode	X			land_status	wwec.mdb	developable_area_section368_centerline_eis	Argonne
Energy Corridor	Section 368 Centerline w/Mode	X			land_status	wwec.mdb	sec368centerline_atts	Argonne
Energy Corridor	Section 368 Zone w/Designation	X			land_status	wwec.mdb	developable_area_section368_zone_eis	Argonne
Energy Corridor	Section 368 Zone w/Designation	X			land_status	wwec.mdb	sec368zone_atts	Argonne
Energy Corridor	Section 368 Zone w/Mode	X			land_status	wwec.mdb	developable_area_section368_zone_eis	Argonne
Energy Corridor	Section 368 Zone w/Mode	X			land_status	wwec.mdb	sec368zone_atts	Argonne
Existing Energy Infrastructure	Alternative Fuel Station	X	X	X	transportation	transportation_fuel.mdb	alternative_fuels_stations_sites	BTS
Existing Energy Infrastructure	Commercial Nuclear Power Plant	X			utilities	utilities.mdb	nuclear_power_plant_site_unique	IAEA, NRC, and others
Existing Energy Infrastructure	CSP Plant Location	X			utilities	utilities.mdb	csp_plant_location	NREL
Existing Energy Infrastructure	Electrical Transmission Line (Alaska)		X		utilities	utilities.mdb	electrical_cable_line_alaska	ASGDC
Existing Energy Infrastructure	National Biodiesel Board Member Plant	X			transportation	transportation_fuel.mdb	nbb_biodiesel_site	National Biodiesel Board
Existing Energy Infrastructure	Pipeline		X		transportation	transportation_pipeline.mdb	alaska_pipelines	ASGDC
Existing Energy Infrastructure	TVA Fossil Power Plant	X			utilities	utilities.mdb	fossil_power_plant_site_TVA	Argonne
Existing Energy Infrastructure	TVA Nuclear Power Plant	X			utilities	utilities.mdb	nuclear_power_plant_site_TVA	Argonne
Existing Energy Infrastructure	FEMA Electric Transmission Lines	X			utilities	utilities.mdb	transmission_line_FEMA	FEMA

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Geology	Geologic Fault	X	X	X	geology	geology.mdb	fault_line	National Atlas of the United States
Geology	Glacial Limit	X			geology	geology.mdb	geologic_feature_site_glacial_limit	National Atlas of the United States
Geology	Impact Structure	X			geology	geology.mdb	geologic_feature_site_impact	National Atlas of the United States
Geology	Karst Area (USGS)	X	X	X	geology	geology.mdb	strata_unit_area_karst	National Atlas of the United States
Geology	Landslide Incidence and Susceptibility	X			environmental_hazards	environmental_hazards	landslide	National Atlas of the United States
Geology	Lava Flow Hazard—Zone Boundary			X	geology	geology.mdb	lava_flow_hazard	Hawaii Statewide GIS Program
Geology	Metamorphic Facie	X			geology	geology.mdb	geologic_feature_site_metamorphic_facies	National Atlas of the United States
Geology	Seismic Hazard	X	X	X	geology	geology.mdb	seismic_hazard	National Atlas of the United States
Geology	Seismic Risk/Areas: Peak Horizontal Acceleration With 10% Probability of Exceedance in 50 Years	X			geology	geology_tectonic.mdb	seismic_risk_zone_area_10pcnt50yr	USGS
Geology	Seismic Risk/Points: Peak Horizontal Acceleration With 10% Probability of Exceedance in 50 Years	X			geology	geology_tectonic.mdb	seismic_risk_point_10pcnt50yr	USGS
Geology	Surface Geology	X	X	X	geology	geology.mdb	geology_survey_area	National Atlas of the United States
Geology	Volcano	X		X	geology	geology.mdb	volcano_site	ESRI
Geology	Volcano		X		geology	geology.mdb	volcano_site	Alaska Volcano Observatory

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Geothermal Resources	Area with Potential for Warm Ground Water			X	geology	geology.mdb	potential_warm_ground_water	Hawaii Statewide GIS Program
Geothermal Resources	Geothermal Feature			X	geology	geology.mdb	geothermal_line	Hawaii Statewide GIS Program
Geothermal Resources	Geothermal Potential/Favorability Surface	X			geology	geology.mdb	western_us_geothermal_favoribility_sites	USGS
Geothermal Resources	Geothermal Potential Area	X	X		geology	geology.mdb	geothermal_potential_area	BLM
Geothermal Resources	Geothermal Potential Area		X		geology	geology.mdb	potential_geothermal_resources	AEDI
Geothermal Resources	Geothermal Project	X			geology	geology.mdb	wrez_geothermal_resources_projects	NREL
Geothermal Resources	Geothermal Resource Subzone, High Temperature Resource Area			X	geology	geology.mdb	geothermal_polygon	Hawaii Statewide GIS Program
Geothermal Resources	Potential Geothermal Resource			X	geology	geology.mdb	geothermal_resources	INL
Geothermal Resources	Thermal Spring			X	geology	geology.mdb	thermal_springs	Hawaii Statewide GIS Program
Geothermal Resources	Well or Spring		X		hydrography	hydrography.mdb	spring_point	AEDI
Government Agency Boundary	BLM Administration Sites	X	X		buildings	buildings.mdb	blm_federal_structure_site	BLM GeoCommunicator
Government Agency Boundary	BLM District Boundary	X	X		boundary	boundary.mdb	district_area_blm_district_admin	BLM GeoCommunicator
Government Agency Boundary	BLM Field Offices and Resource Areas	X	X		boundary	boundary.mdb	district_area_blm_fora_admin	BLM GeoCommunicator
Government Agency Boundary	BLM Grazing Allotment	X			land_status	land_status.mdb	land_management_zone_area_blm_grazing	GeoCommunicator
Government Agency Boundary	BLM Range Allotment Pasture	X			land_status	land_status.mdb	land_management_zone_area_blm_pasture	GeoCommunicator

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Government Agency Boundary	BLM State Jurisdiction Boundary	X	X		boundary	boundary.mdb	district_area_blm_state_admin	BLM GeoCommunicator
Government Agency Boundary	Federal Government Administered Land	X	X	X	cadastre	cadastre.mdb	agency_owned_area_anl_090914	BLM NILS
Government Agency Boundary	Federal Rights-of-Way	X			cadastre	cadastre.mdb	federal_property_interest_site_blm_closed, fiber optics, general, other, pipeline, power, railroad, road, telephone, water	BLM GeoCommunicator
Government Agency Boundary	FWS Administration Sites	X	X	X	buildings	buildings.mdb	fws_federal_structure_site	FWS
Government Agency Boundary	State Administered Land	X	X		cadastre	cadastre.mdb	agency_owned_area_state_080924	BLM NILS
Government Agency Boundary	Tribal Corporation		X		cadastre	cadastre.mdb	alaska_tribal_corporations	ASGDC
Government Agency Boundary	Tribal Land	X			cadastre	cadastre.mdb	agency_owned_area_tribal_090914	BLM NILS
Government Agency Boundary	U.S. Forest Service Ranger District	X	X		boundary	boundary.mdb	district_area_fs_ranger_dist	USFS
Government Agency Boundary	U.S. Forest Service Region	X	X	X	boundary	boundary.mdb	district_area_fs_region	USFS
Government Agency Boundary	U.S. General Services Administration Region	X	X		boundary	boundary.mdb	district_area_gsa_region	ESRI, GSA, Argonne
Government Agency Boundary	USFS Range Allotment	X			land_status	land_status.mdb	land_management_zone_area_usfs	GeoCommunicator
Hydrogen Resources	Hydrogen Potential from Resources	X	X	X	climate	climate_hydrogen.mdb	energy_potential_hydrogen	NREL
Hydrography	Aquifer	X		X	hydrography	hydrography.mdb	aquifer	National Atlas of the United States
Hydrography	Dam/Lock	X	X	X	hydrography	hydrography.mdb	dam_lock_site	National Atlas of the United States

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Hydrography	Gauging Station	X	X	X	hydrography	improvement.mdb	realtime_streamflow_station_point	National Atlas of the United States
Hydrography	Great Lake	X			hydrography	hydrography.mdb	surface_water_body_area_great_lakes	National Atlas of the United States
Hydrography	Hydrologic Unit	X		X	hydrography	hydrography.mdb	hydrologic_units	National Hydrography Dataset
Hydrography	Hydrologic Unit		X		hydrography	hydrography.mdb	hydrologic_units	USGS
Hydrography	Navigable Waterway Network	X	X	X	hydrography	hydrography.mdb	navigable_waterway_network	BTS
Hydrography	Pump Storage	X			hydrography	hydrography.mdb	pump_storage_site	Argonne
Hydrography	Stream/River	X	X	X	hydrography	hydrography.mdb	surface_water_course_centerline	National Atlas of the United States
Hydrography	TVA Reservoir	X			hydrography	hydrography.mdb	reservoir_management_area_TVA	Argonne
Hydrography	Water Body	X	X	X	hydrography	hydrography.mdb	surface_water_body_area	National Atlas of the United States
Hydropower Resources	Hydropower Potential Reach (Idaho National Laboratory)	X	X	X	hydrography	hydrography.mdb	surface_water_course_centerline_inl_study	Idaho National Laboratory
Hydropower Resources	Hydropower Potential Site (Idaho National Laboratory)	X	X	X	hydrography	hydrography.mdb	surface_water_course_point_inl_study	Idaho National Laboratory
Hydropower Resources	Hydropower Resource	X			hydrography	hydrography.mdb	wrez_hydro_resources	NREL WREZ
Methane Resources	TVA Green Power Switch® Methane Site	X			utilities	utilities.mdb	green_power_switch_methane_site_TVA	Argonne
Other Energy Resources	Coal Basin, Region or Field	X	X		geology	geology.mdb	coal_basin_regions_fields	EIA
Other Energy Resources	Coalbed Methane Field	X	X		geology	geology.mdb	coalbed_methane_fields	EIA
Other Energy Resources	Mineral Resource	X	X	X	land_status	land_status.mdb	mine_site	USGS
Other Energy Resources	North American CO2 Source	X	X	X	environmental_hazards	environmental_hazards	CO2_sources	NETL
Other Energy Resources	North American Oil & Gas Field	X	X		geology	geology.mdb	oil_and_gas_reservoirs	NETL

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Other Energy Resources	North American Saline Basin	X	X		geology	geology.mdb	deep_saline_formations	NETL
Other Energy Resources	Oil Shale Area	X			geology	geology.mdb	oil_shale_areas	BLM GeoCommunicator
Other Energy Resources	Oil Shale Closed Area	X			geology	geology.mdb	oil_shale_closed_areas	BLM GeoCommunicator
Other Energy Resources	Oil Shale Prospective Area	X			geology	geology.mdb	oil_shale_prospective_areas	BLM GeoCommunicator
Other Energy Resources	Shale Gas Basin	X			geology	geology.mdb	shale_gas_basins	EIA
Other Energy Resources	Shale Gas Play, Stacked Shale Gas Play	X			geology	geology.mdb	shale_gas_plays	EIA
Other Energy Resources	Unmineable Coal Seam	X	X		geology	geology.mdb	unmineable_coal_seams	NETL
Protected Areas	Area of Critical Environmental Concern	X			land_status	land_status.mdb	land_restriction_area_acec	Various
Protected Areas	Battlefields and Military Parks/Sites (NPS)	X			land_status	land_status.mdb	land_restriction_area_nps_battlefields	NPS
Protected Areas	BLM National Conservation Area	X			land_status	land_status.mdb	land_restriction_area_blm_conservation_areas	BLM
Protected Areas	Class I Area—NPS		X	X	visual	visual.mdb	visual_management_area_nps	National Park Service
Protected Areas	Class I Area—Tribal	X			visual	visual.mdb	visual_management_area_epa	EPA
Protected Areas	Class I Area—USFS				visual	visual.mdb	visual_management_area_usfs	National Park Service
Protected Areas	Class I Area—USFWS		X		visual	visual.mdb	visual_management_area_fws	National Park Service
Protected Areas	Designated Wilderness by Agency	X			land_status	land_status.mdb	land_restriction_area_wilderness_anl4	BLM NLCS
Protected Areas	Experimental Research Forest/Area	X			land_status	land_status.mdb	land_restriction_area_experimental_research_forest	USGS GAP Analysis Program, NBII
Protected Areas	FWS Critical Habitat Area	X	X	X	land_status	land_status.mdb	land_restriction_area_fws_critical_habitat	USFWS

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Protected Areas	Grand Portage National Monument	X			hydrography	hydrography.mdb	surface_water_course_centerline_wsrs_mon	Wild & Scenic River System Organization
Protected Areas	Military Special Use Airspace (DOD)	X			military_operations	military_operations.mdb	special_use_airspace_site	SRS Technologies
Protected Areas	Military Training Route (DOD)/MTR—Instrument Corridor	X			military_operations	military_operations.mdb	military_flight_corridor_area_ir	SRS Technologies
Protected Areas	Military Training Route (DOD)/MTR—Low-level Corridor	X			military_operations	military_operations.mdb	military_flight_corridor_area_sr	SRS Technologies
Protected Areas	Military Training Route (DOD)/MTR—Visual Corridor	X			military_operations	military_operations.mdb	military_flight_corridor_area_vr	SRS Technologies
Protected Areas	Military Training Route (DOD)/MTR Centerline	X			military_operations	military_operations.mdb	military_route_line	SRS Technologies
Protected Areas	National Conservation or Recreational Area (NLCS)		X		land_status	land_status.mdb	land_restriction_area_nlcs	BLM NLCS
Protected Areas	National Monument (Compiled)	X	X		land_status	land_status.mdb	land_restriction_area_nat_mon	Various
Protected Areas	National Park	X	X	X	cadastre	cadastre.mdb	agency_owned_area_national_park	National Park Service
Protected Areas	National Park Service Property	X	X	X	improvement	improvement_recreation.mdb	recreation_park_area	National Park Service
Protected Areas	National Parkway	X			transportation	transportation_roads.mdb	road_centerline_nlcs_nat_pkwy	Wild & Scenic River System Organization
Protected Areas	National Recreation Area (BLM)	X			land_status	land_status.mdb	land_restriction_area_blm_national_recreation_areas	BLM
Protected Areas	National Recreation Area (NPS)	X			land_status	land_status.mdb	land_restriction_area_nps_national_recreation_areas	NPS
Protected Areas	National Recreation Area (USFS)	X			land_status	land_status.mdb	land_restriction_area_usfs_national_recreation_areas	BLM
Protected Areas	National Scenic or Backcountry Byway	X	X	X	visual	visual.mdb	scenic_backcountry_byways	National Scenic Byway Organization
Protected Areas	National Trail	X	X		improvement	improvement_recreation.mdb	recreation_trail_centerline	Argonne
Protected Areas	National Trail (FWS)	X	X	X	improvement	improvement_recreation.mdb	recreation_trail_centerline_fws	FWS

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Protected Areas	National Wildlife Refuge				cadastre	cadastre.mdb	agency_owned_area_fws_refuge	BLM NILS
Protected Areas	Protected Areas Database	X	X	X	land_status	protected_areas_database.mdb	land_restriction_protected_areas_database	USGS GAP Analysis Program, NBII
Protected Areas	Research Natural Areas	X			land_status	land_status.mdb	land_restriction_area_research_natural_area	USGS GAP Analysis Program, NBII
Protected Areas	The Nature Conservancy's Land	X		X	land_status	land_status.mdb	land_restriction_area_nature_conservancy	The Nature Conservancy
Protected Areas	USFS Roadless Area	X	X		land_status	land_status.mdb	land_restriction_area_usfs_roadless	U.S. Forest Service
Protected Areas	USFS Specially Designated Area	X	X		land_status	land_status.mdb	land_restriction_area_usfs_sda	U.S. Forest Service
Protected Areas	Wild and Scenic River (WSRS)		X		hydrography	hydrography.mdb	surface_water_course_centerline_nlcs_wsr	BLM NLCS
Protected Areas	Wild and Scenic River (WSRS)	X	X	X	hydrography	hydrography.mdb	surface_water_course_centerline_wsrs_wsr	Wild & Scenic River System Organization
Protected Areas	Wilderness Area (National Atlas)	X	X	X	land_status	land_status.mdb	land_restriction_area_wilderness_nat_atlas	National Atlas of the United States
Protected Areas	Wilderness Study Area (BLM)	X			land_status	land_status.mdb	land_restriction_area_wsa_anl2	BLM NLCS
Protected Areas/EPA Environmental Hazard Site	Environmental Hazard Site (EPA)	X	X	X	environmental_hazards	env_haz_air_pollution.mdb	epa_environmental_hazard_site	EPA
Protected Areas/Formerly Used Defense Site (DOD)	Formerly Used Defense Site (DOD)	X	X	X	environmental_hazards	env_haz_air_pollution.mdb	dod_formerly_used_defense_site	Army Corps of Engineers
Protected Areas/National Ambient Air Quality Standard Area	NAAQS Area—Carbon Monoxide	X			environmental_hazards	env_haz_air_pollution.mdb	air_pollution_nonattainment_area_co	EPA

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Protected Areas/National Ambient Area Air Quality Standard Area	NAAQS Area—Lead	X			environmental_hazards	env_haz_air_pollution.mdb	air_pollution_nonattainment_area_pb	EPA
Protected Areas/National Ambient Area Air Quality Standard Area	NAAQS Area—Nitrogen Dioxide	X			environmental_hazards	env_haz_air_pollution.mdb	air_pollution_nonattainment_area_no2	EPA
Protected Areas/National Ambient Area Air Quality Standard Area	NAAQS Area—Ozone: 1-hour	X			environmental_hazards	env_haz_air_pollution.mdb	air_pollution_nonattainment_area_o3_1hour	EPA
Protected Areas/National Ambient Area Air Quality Standard Area	NAAQS Area—Ozone: 8-hour	X			environmental_hazards	env_haz_air_pollution.mdb	air_pollution_nonattainment_area_o3_8hour	EPA
Protected Areas/National Ambient Area Air Quality Standard Area	NAAQS Area—PM ₁₀	X			environmental_hazards	env_haz_air_pollution.mdb	air_pollution_nonattainment_area_pm10	EPA
Protected Areas/National Ambient Area Air Quality Standard Area	NAAQS Area—PM _{2.5}	X			environmental_hazards	env_haz_air_pollution.mdb	air_pollution_nonattainment_area_pm25	EPA
Protected Areas/National Ambient Area Air Quality Standard Area	NAAQS Area—Sulfur Dioxide	X			environmental_hazards	env_haz_air_pollution.mdb	air_pollution_nonattainment_area_so2	EPA

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Solar Resources	Concentrating Solar Power (Direct Normal) (NREL) 10 km	X	X	X	climate	climate_solar.mdb	energy_potential_solar_csp	NREL
Solar Resources	Concentrating Solar Power (Direct Normal) Potential	X			climate	climate_solar.mdb	energy_potential_solar_conc	NREL
Solar Resources	Concentrating Solar Prospects SW U.S./Slope Filter Less than 1%	X			climate	climate_solar2.mdb	csp_southwest_filter_1percent	NREL
Solar Resources	Concentrating Solar Prospects SW U.S./Slope Filter Less than 2%	X			climate	climate_solar2.mdb	csp_southwest_filter_2percent	NREL
Solar Resources	Concentrating Solar Prospects SW U.S./Slope Filter Less than 3%	X			climate	climate_solar2.mdb	csp_southwest_filter_3percent	NREL
Solar Resources	Concentrating Solar Prospects SW U.S./Slope Filter Less than 4%	X			climate	climate_solar2.mdb	csp_southwest_filter_4percent	NREL
Solar Resources	Concentrating Solar Prospects SW U.S./Slope Filter Less than 5%	X			climate	climate_solar.mdb	csp_southwest_filter_5percent	NREL
Solar Resources	Photovoltaic Potential	X			climate	climate_solar.mdb	energy_potential_solar_pv	NREL
Solar Resources	Tilted Photovoltaic Potential	X		X	climate	climate_solar.mdb	energy_potential_solar_pvtilt	NREL
Solar Resources	TVA Green Power Switch® Solar Site	X			utilities	utilities.mdb	green_power_switch_solar_site_TVA	Argonne
Wind Resources	Installed Wind Energy Capacity	X			utilities	utilities.mdb	installed_wind_energy_capacity	American Wind Energy Assoc.
Wind Resources	NREL National Wind Resource Assessment (High Res)	X			climate	climate_wind2.mdb	energy_potential_wind_highres	NREL
Wind Resources	NREL National Wind Resource Assessment (Low Res)	X	X	X	climate	climate_wind.mdb	energy_potential_wind_lowres	NREL

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Wind Resources	Offshore Wind Resources (NREL, 90 m)	X			climate	climate_wind2.mdb	offshore_energy_potential_wind	NREL
Wind Resources	Offshore Wind Resources (NREL, 90 m)	X		X	climate	climate_wind.mdb	offshore_potential_wind_atlantic, pacific, gulf_mexico, great_lakes, hawaii	NREL
Wind Resources	TVA Green Power Switch@ Wind Site	X			utilities	utilities.mdb	green_power_switch_wind_site_TVA	Argonne
Wind Resources	Wind Resources by State (NREL, 50 m)	X	X	X	climate	climate_wind.mdb	energy_potential_wind_ia, nd, sd, mn, mt, ne, ar, il, in, ks, ky, mi, midatl, mn, mo, mt, new england, oh, ok, prvi, ca, pacific northwestern, az, nv, ut, co, nm, hi, ak, tn, tx	NREL

9. REFERENCES

Bentek Energy, 2012, *POWERMap™*. Available at <http://www.bentekenergy.com/POWERmap.aspx>. Accessed March 16, 2012.

BLM (U.S. Department of the Interior, Bureau of Land Management), 2008, *Final Programmatic Environmental Impact Statement, Designation of Energy Corridors on Federal Land in the 11 Western States*, DOE/EIS-0386, Washington D.C., Nov. Available at <http://corridoreis.anl.gov/eis/guide/index.cfm>. Accessed March 9, 2012.

DOE (U.S. Department of Energy)/BLM, 2010, *Draft Programmatic Environmental Impact Statement for Solar Energy Development in Six Southwestern States*, DES 10-59, DOE/EIS-0403, Dec. Available at <http://solareis.anl.gov/documents/dpeis/index.cfm>. Accessed March 15, 2012.

DOE/BLM, 2011, *Supplement to the Draft Programmatic Environmental Impact Statement for Solar Energy Development in Six Southwestern States*, DES 11-49, DOE/EIS-0403D-S, Oct. Available at <http://solareis.anl.gov/documents/supp/index.cfm>. Accessed March 15, 2012.

DOE, 2010a, *Energy Efficiency & Renewable Energy: Concentrating Solar Power: Parabolic Trough System Image*. Available at http://www.eere.energy.gov/basics/renewable_energy/linear_concentrator.html. Accessed March 8, 2012.

DOE, 2010b, *Energy Efficiency & Renewable Energy: Concentrating Solar Power: Linear Fresnel Reflector System Image*. Available at http://www.eere.energy.gov/basics/renewable_energy/linear_concentrator.html. Accessed March 8, 2012.

DOE, 2010c, *Energy Efficiency & Renewable Energy: Concentrating Solar Power: Power Tower System Image*. Available at http://www.eere.energy.gov/basics/renewable_energy/power_tower.html. Accessed March 9, 2012.

DOE, 2010d, *Energy Efficiency & Renewable Energy: Concentrating Solar Power: Dish/Engine System Image*. Available at http://www.eere.energy.gov/basics/renewable_energy/dish_engine.html. Accessed March 9, 2012.

DOE, 2010e, *Diagram of a Photovoltaic Cell Image*. Available at http://www.eere.energy.gov/basics/renewable_energy/images/illust_materials.gif. Accessed March 9, 2012.

DOE, 2010f, *Inside the Wind Turbine Image*. Available at http://www1.eere.energy.gov/images/illust_large_turbine.gif. Accessed March 9, 2012.

DOE, 2010g, *Dry Steam Power Plant Image*. Available at <http://www1.eere.energy.gov/geothermal/powerplants.html#drysteam>. Accessed March 9, 2012.

DOE, 2010h, *Flash Steam Power Plant Image*. Available at <http://www1.eere.energy.gov/geothermal/powerplants.html#flashsteam>. Accessed March 9, 2012.

DOE, 2010i, *Binary Cycle Power Plant Image*. Available at <http://www1.eere.energy.gov/geothermal/powerplants.html#binarycycle>. Accessed March 9, 2012.

DOE, 2010j, *Resource-Based Biorefinery Pathways Image*. Available at http://www1.eere.energy.gov/biomass/feedstocks_types.html. Accessed March 8, 2012.

DOE, 2011, *2010 Renewable Energy Data Book*, Energy Efficiency and Renewable Energy. Available at <http://www.nrel.gov/analysis/pdfs/51680.pdf>. Accessed March 26, 2010.

DOT (U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration), 2012, *National Pipeline Mapping System*. Available at <http://www.npms.phmsa.dot.gov>. Accessed March 16, 2012.

Google, 2012, *Google Earth*. Available at <http://www.google.com/intl/en/earth/index.html>. Accessed March 19, 2012.

Hart Energy, 2012, *Oil and Gas Mapping Services*. Available at <http://www.hartenergy.com/Midstream/Data-Services/Mapping-And-GIS-Services>. Accessed March 16, 2012.

INEEL (Idaho National Engineering and Environmental Laboratory), 2004, *Water Energy Resources of the United States with Emphasis on Low Head/Low Power Resources*, DOE/ID-11111. Available at <http://hydropower.inel.gov/resourceassessment/pdfs/03-11111.pdf>. Accessed March 26, 2012.

NASA, 2012, *NASA World Wind*. Available at http://worldwindcentral.com/wiki/NASA_World_Wind_Download. Accessed March 8, 2012.

NREL (National Renewable Energy Laboratory), 1998, *Wind Turbines at the Foote Creek Rim Project Image*. Available at <http://www.nrel.gov/data/pix/Jpegs/06591.jpg>. Accessed March 9, 2012.

NREL, 2007a, *Nevada Solar One Solar Field Image*. Available at <http://www.nrel.gov/data/pix/Jpegs/14947.jpg>. Accessed March 9, 2012.

NREL, 2007b, *SunPower T20 Trackers at Nellis Air Force Base Image*. Available at <http://www.nrel.gov/data/pix/Jpegs/15280.jpg>. Accessed March 9, 2012.

NREL, 2010a, *Geothermal Energy Plant at Calpine's The Geysers Image*. Available at <http://www.nrel.gov/data/pix/Jpegs/17270.jpg>. Accessed March 9, 2012.

NREL, 2010b, *eSolar Sierra SunTower Power Tower Plant Image*. Available at <http://www.nrel.gov/data/pix/Jpegs/18394.jpg>. Accessed March 9, 2012.

NREL, 2010c, *Maricopa Solar Power Plant Dish Image*. Available at <http://www.nrel.gov/data/pix/Jpegs/18378.jpg>. Accessed March 9, 2012.

USACE (U.S. Army Corps of Engineers), 2010a, *Chief Joseph Dam Aerial Spill Image*. Available at <http://eportal.usace.army.mil/sites/DVL/DVL%20Images/Forms/DispForm.aspx?ID=4018>. Accessed March 9, 2012.

USACE, 2010b, *How Chief Joseph Dam Run-of-the-River System Works Image*. Available at <http://www.nws.usace.army.mil/publicmenu/images/cjdam/powerhouse.jpg>. Accessed March 9, 2012

USACE, 2012, *Lock & Dam 2 Mississippi River Image*. Available at <http://eportal.usace.army.mil/sites/DVL/DVL%20Images/Forms/DispForm.aspx?ID=3583>. Accessed March 9, 2012.

USBR (U.S. Bureau of Reclamation), 2007, *Aerial Hoover Dam Image*. Available at <http://www.usbr.gov/lc/images/gallery/hoover/C45-300-102.jpg>. Accessed March 9, 2012.

WAPA (U.S. Department of Energy, Western Area Power Administration)/USFWS (U.S. Department of Interior, Fish and Wildlife Service), 2010, *Upper Great Plains Wind Energy Programmatic Environmental Impact Statement* (in progress). Available at <http://plainswindeis.anl.gov>. Accessed March 9, 2012.