RENEWABLE ENERGY ATLAS

OF THE UNITED STATES

ANL/EVS-13/2
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PREPARED BY
ARGONNE NATIONAL LABORATORY

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DEFINITIONS

AEDI	Alaska Energy Data Inventory
Argonne	Argonne National Laboratory
ASGDC	Alaska State Geo-spatial Data Clearinghouse
Atlas	Renewable Energy Atlas
BLM	U.S. Bureau of Land Management
CSP	concentrating solar power
DOE	U.S. Department of Energy
EIA	Energy Information Administration
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ESRI	Environmental Systems Research Institute
FWS	U.S. Fish and Wildlife Service
GIS	Geographic Information System
HTF	heat transfer fluid
INL	Idaho National Laboratory
KDF	Knowledge Discovery Framework
NBII	National Biological Information Infrastructure
NETL	National Energy Technology Laboratory
NFS	National Forest Service
NLCS	National Landscape Conservation System
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NREL	National Renewable Energy Laboratory
ORNL	Oak Ridge National Laboratory
PEIS	Programmatic Environmental Impact Statement
PV	photovoltaic
READ-Database	Renewable Energy and Defense Geospatial Database
RITA-BTS	Research and Innovative Technology Administration's Bureau of Transportation Statistics
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture

USFS
USGS

U.S. Forest Service
U.S. Geological Survey

Virginia Tech

Virginia Polytechnic Institute and State University

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 (USDA), U.S. 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 by Argonne National Laboratory (Argonne) to support recent and current energy-related Environmental Impact Statements and studies, including the following projects:

- Eastern Interconnection States' Planning Council Energy Zones Mapping Tool (Argonne 2013),
- Draft Upper Great Plains Wind Energy PEIS (WAPA/USFWS 2013),
- Final PEIS for Solar Energy Development in Six Southwestern States (BLM/DOE 2012),
- West-wide Energy Corridor Programmatic Environmental Impact Statement (PEIS) (BLM 2008),
- Energy Transport Corridors: The Potential Role of Federal Lands in States Identified by the Energy Policy Act of 2005, Section 368(b) (Krummel, et al. 2011).

This report explains how to add the Atlas to your computer and install the associated software. The report also includes:

- A description of each of the components of the Atlas;
- Lists of the Geographic Information System (GIS) database content and sources; and
- A brief introduction to the major renewable energy technologies.

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2. CONTENT OF THE ATLAS

The Atlas includes the following:

- A GIS database organized as a set of Environmental Systems Research Institute (ESRI) ArcGIS Personal GeoDatabases, and
- ESRI ArcReader and ArcGIS project files providing an interactive map visualization and analysis interface.

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3. INSTALLING ARCREADER AND NAVIGATING THE ATLAS

ESRI ArcReader 10.1, ArcGIS ArcView 10.1, 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 the product in use. (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 10.1 (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 Renewable_Energy_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 Alaska and Hawaii. Figure 3-1 presents 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 order of how they appear in the table of contents. In ArcView, drag a layer in the table of contents to a position higher than a layer obscuring it to make it draw above the ones listed after it. 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 require more 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**. Alternatively, **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 that focus exclusively on Alaska and Hawaii are also provided.

- 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 U.S. Geological Survey (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 energy resources, federal land ownership, and base map reference 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 located east of Seattle Washington. The Hydrography Group in the Atlas includes hydrologic units (watersheds); 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 2013) 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 (2013), Hart Energy (2013), 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. RENEWABLE ENERGY TECHNOLOGIES

This section briefly describes the major renewable energy technologies with examples of installed projects.

5.1 SOLAR POWER

Solar collectors 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 heat a fluid. The heated fluid 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 contrast to CSP, PV technologies convert the photons in sunlight directly to electricity.

Solar power generation is variable due to the daily cycle of the sun's angle and weather factors such as cloud cover. PV panels also vary in efficiency at different temperatures. The variable and somewhat unpredictable nature of solar power generation adds complexity to integrating these plants into the electrical transmission grid. Co-locating them with energy storage systems such as pumped hydroelectric storage or compressed air energy storage is advantageous for mitigating the variability.

5.1.1 LINEAR CONCENTRATORS

These are CSP systems that use mirrors to focus solar energy on receiver tubes containing a heat transfer fluid. The fluid in the receiver tubes is heated by the solar energy and used to create superheated steam, which spins turbines that run a generator to create electricity. The major components of a 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: the more common parabolic trough systems, 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 5.1-1). The linear Fresnel reflector system uses flat mirrors to heat water directly in the receiver tubes (Figure 5.1-2). Parabolic trough facilities may include thermal energy storage capability, whereby excess generated heat is stored in a thermal storage medium, typically molten salt, then used during hours without sunlight.

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 5.1-1 Concentrating Solar Power Systems: Parabolic Trough Systems (DOE 2010a).

Figure 5.1-2 Concentrating Solar Power Systems: Linear Fresnel Reflector System (DOE 2010b).

Example Solar Linear Concentrator Project

The Nevada Solar One project includes a 400-acre solar field and has a power capacity of 75 MW (Figure 5.1-3). This system consists of 760 parabolic troughs with 182,000 mirrors and 18,240 receiver tubes, each 4 m in length.

Figure 5.1-3 Nevada Solar One Parabolic Trough Facility (NREL 2007a).

5.1.2 SOLAR POWER TOWER

The major components of a typical utility-scale power tower facility are the solar field, tower, power block, and cooling system. Utility-scale power tower facilities are CSP plants consisting of thousands of flat mirrors called heliostats that direct solar energy towards a central tower (Figure 5.1-4). The typical height of a solar power tower is about 300 to 450 ft. The heliostats are equipped with systems that track the sun from east to west to maximize power capture, then concentrate the solar energy on a central point at the top of the tower, where a heat transfer fluid (HTF) absorbs the heat. The HTF creates superheated steam, which spins turbines that run a generator to create electricity. Molten salts have replaced water as the HTF, because they have greater thermal energy storage capabilities. Power tower facilities may include thermal energy storage capability, whereby excess generated heat is stored in a thermal storage medium, typically molten salt, then used during hours without sunlight.

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

Figure 5.1-4 Concentrating Solar Power Systems: Power Tower System (DOE 2010c).

Example Solar Power Tower System

Sierra Sun Tower is a power tower demonstration facility located outside of Lancaster, California, encompassing 20 acres and operated by eSolar (Figure 5.1-5). The eSolar system is modular, using multiple 180-ft. power towers, each with a set of 12,000 heliostats. The Lancaster facility has two modules, each with a capability of generating 2.5 MW of power, for a total of 5 MW.

Figure 5.1-5 eSolar's Sierra SunTower Facility outside of Lancaster, California (NREL 2010b).

5.1.3 SOLAR DISH ENGINE SYSTEMS

These 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 (Figure 5.1-6). 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, which powers the generator and produces 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 5.1-6 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 5.1-7). 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 5.1-7 SunCatcher Solar Dish Engines at the Maricopa Solar Power Plant (NREL 2010c).

5.1.4 PHOTOVOLTAIC SYSTEMS

Photovoltaic 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, modules made up of many individual solar cells are combined to make individual solar panels, and these panels are grouped into arrays that produce direct current (DC) electricity (Figure 5.1-8). 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 the sun's energy onto a smaller area. As such, it requires less solar cell material compared to flat plate systems that generate the same amount of electricity. While solar cell efficiency is increased in PV concentrator systems, disadvantages include their expensive optics, the added cost of sun-tracking systems, and excess heat.

To learn more about PV technology, visit

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

Figure 5.1-8 Diagram of a Photovoltaic Cell (DOE 2010e).

Example Solar Photovoltaic Systems

Two examples of PV projects are the DeSoto Next Generation Solar Energy Center in DeSoto County, Florida, and the Nellis Air Force Base Solar Power System. The 180-acre DeSoto facility has more than 90,000 solar panels that have the capacity to generate 25 MW. 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 with a generation capacity of 14.2 MW (Figure 5.1-9). The 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 5.1-9 Photovoltaic Solar Power System at Nellis Air Force Base (NREL 2007b).

5.2 WIND POWER

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 (Figure 5.2-1).

Figure 5.2-1 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 MW of electricity. Some smaller scale wind turbines (100 kW or lower) are used by individuals and businesses. With a cost between 5 and 8 cents per kWh, wind power is one of the cheapest forms of renewable energy. 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 is usually an intermittent resource, and a backup source of energy may be needed for utility-scale facilities; a significant proportion of wind resources are in remote areas without existing transmission lines, thereby increasing the costs of tying them to the grid; 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 and the Foote Creek Rim Project are two examples of wind energy development facilities. The Horse Hollow Wind Energy Center, located on 47,000 acres of land in Taylor and Nolan counties in 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 of the windiest places in the United States (Figure 5.2-2). 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 5.2-2 Wind Turbines at the Foote Creek Rim Project near Arlington, Wyoming (NREL 1998).

5.3 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. Wells can be drilled to access their steam and very hot water for use 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 from the source into buildings or other facilities for heating purposes. Geothermal heat pump systems use the stable temperatures at the upper 10 feet of the earth's surface to heat and cool buildings by circulating water through the shallow ground and employing a heat-exchange system.

Three types of technologies are used for geothermal power plants: dry steam, flash steam, and binary cycle. All three types recycle the hot water and inject the remaining geothermal fluid back into a reservoir. In addition, geothermal power plants require a cooling system that prevents the turbines from overheating, which ultimately extends the life of the facility.

1. In dry steam plants, the steam is used directly to spin turbines that drive a generator to create electricity (Figure 5.3-1).

2. In flash steam plants, steam or water under high temperatures and/or pressures is directed into a tank at lower pressure, thereby flashing the vapor. The flashed vapor is used to spin turbines that drive an electrical generator (Figure 5.3-2).

3. In a binary cycle plant, geothermal fluids are used to boil a “working” fluid such as butane or pentane that has a boiling point lower than water, and the flash of the binary fluid is used to spin the turbines (Figure 5.3-3).

Figure 5.3-1 Dry Steam Geothermal Power Plant (DOE 2010g).

Figure 5.3-2 Flash Steam Geothermal Power Plant (DOE 2010h).

Figure 5.3-3 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 Mammoth Pacific Complex (Figure 5.3-4) is a binary-cycle geothermal power plant located in central California, near Bishop (Ormat 2013a). The plants are fueled by geothermal brine from the Casa Diablo Hot Springs. Mammoth Pacific I was built in 1984 and generates 10 megawatts. The two other projects were built in 1990 and generate 15 megawatts. The projects consist of 12 production wells and 8 injection wells. A total of eight single-stage, radial-flow gas expanders are used (GEA 2013). A federal permit for the Casa Diablo IV Geothermal Development Project, a 33-megawatt expansion of the plant on Inyo National Forest and adjacent private lands, was approved in 2013 (BLM et al. 2013). The USFS has also completed an Environmental Impact Statement and Record of Decision for Geothermal Leasing on the Humboldt Toiyabe National Forest in Northeast Nevada. The action made approximately 662,700 acres of NFS lands available for geothermal leasing (USFS 2012).

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. The Geysers has the capacity to generate 1,517 MW of electricity and is the largest dry steam power plant in the United States. It is also the first successful demonstration of EGS technologies in the United States. Approximately 250 MW of energy are generated at The Geysers on land leased from the federal government. Puna Geothermal Venture, located in Puna, on the Big Island of Hawaii, uses binary cycle technology 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.

Figure 5.3-4 Mammoth Geothermal Power Plant, Located on Inyo National Forest and Adjacent Private Land (Ormat 2013b).

5.4 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. That energy remains in plants and animals 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, landfill waste, manure, sanitary wastewater, animal waste from slaughterhouses, grease from restaurants, and forest residue (Figure 5.4-1).

Some crops are grown for the specific purpose of being used for energy production. Termed “dedicated energy crops,” they 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 into 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 algae for the production of 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) carbohydrates are separated and the sugar is released through 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 into 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 then be burned to produce heat or create energy, or go through a thermochemical process to produce 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 and carbon monoxide ratio (gas cleanup and conditioning); (3) the feedstock is heated in the absence of oxygen, which breaks down the product 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).

Forest residues—leftover wood and plant material from logging operations and forest management procedures—are not dedicated energy crops, but are still a sustainable biomass option. Through the use of forest residues, agricultural residues, and dedicated energy crops, the DOE estimates that the United States can grow enough productive biomass to offset more than 30% of the nation's petroleum consumption.

Toward this end, ThermoChem Recovery International is working on methods of processing forest residues for uses other than in co-firing or for heat. The company has tested and validated a process to convert forest residues into diesel fuel and paraffin waxes. Biomass technologies have proven effective in large or small scale productions and can be sustainably maintained.

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.

Figure 5.4-1 Forms of Biomass That Can Be Converted to Energy (DOE 2010j).

Example Biomass Energy Projects

There are a number of biofuel research endeavors currently underway at working production centers around the country. The Biofuels Center of North Carolina, in Oxford, conducts research on using forest residues and mill residues, and studies tree species suitable for conversion into biofuels. 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 that 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 wastewater-derived methane. The Michigan State University Forest Biomass Innovation Center, in Escanaba, Michigan, researches and develops ways to make fuels from cellulose using dedicated energy crops.

5.5 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 5.5-1). 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 5.5-2). In these systems, some or all of the river water is diverted through a penstock and into turbines to generate electricity (Figure 5.5-3), 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 5.5-4). 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

Federal government sources indicate that approximately 2,350 dams exist on NFS lands, and about 18% generate hydropower (USFS 2007, USACE 2013). Shasta Dam, within Shasta National Forest in Northern California, is one of the largest hydropower facilities within NFS lands. It is operated by the U.S. Bureau of Reclamation and had a net generation of 1,806,476,000 kWh in 2009 (USBR 2009).

At the other end of the generation range, Spotted Bear Ranger Station in the Flathead National Forest in western Montana has an example of a USFS micro-hydro project. When water levels are adequate, the system can supply enough electricity to power the 31-building compound (USDA 2012).

Hoover Dam is located on the Colorado River near Boulder City, Nevada (Figure 5.5-1). 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 5.5-1 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 5.5-2). The plant has been operational since 1958 and its current energy generating capacity is 2,620 MW.

Figure 5.5-2 Chief Joseph Dam a Run-of-the-River Hydropower Plant (USACE 2010a).

Figure 5.5-3 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 5.5-4 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 Alaskan Demonstration Site, in Ruby, Alaska, is at full deployment and has a generating capacity of 5 kW.

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6. GIS DATABASE INVENTORY

Table 6.1 is a listing of the geographic information systems (GIS) database inventory, listed alphabetically by ArcReader Group.

Table 6.1 GIS Database Inventory, by ArcReader Group

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	Environmental Systems Research Institute (ESRI)
Base Map	County Label	X	X	X	boundary	boundary.mdb	jurisdiction_county_area	Environmental Systems Research Institute (ESRI)
Base Map	Elevation Contour (1000-ft)		X		landform	landform.mdb	elevation_contour_line	Alaska State Geo-spatial Data Clearinghouse (ASGDC)
Base Map	Elevation Contour (1000-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	Research and Innovative Technology Administration's Bureau of Transportation Statistics
Base Map	Non-U.S. Country	X	X		boundary	boundary.mdb	jurisdiction_country_area	Environmental Systems Research Institute (ESRI)
Base Map	Population Density	X	X	X	demographics	demographics.mdb	census_tract_area	United States Census Bureau
Base Map	State Background	X	X	X	boundary	boundary.mdb	jurisdiction_state_area	Environmental Systems Research Institute (ESRI)
Base Map	Transportation Infrastructure/Airport	X	X	X	transportation	transportation_airports.mdb	airport_polygons	Environmental Systems Research Institute (ESRI)

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Base Map	Transportation Infrastructure/Airport	X	X	X	transportation	transportation_airports.mdb	airfield_centerline	Research and Innovative Technology Administration's Bureau of Transportation Statistics (RITA-BTS)
Base Map	Transportation Infrastructure/Airport	X	X	X	transportation	transportation_airports.mdb	airfield_site	Research and Innovative Technology Administration's Bureau of Transportation Statistics (RITA-BTS)
Base Map	Transportation Infrastructure/Hazardous Material Route	X	X	X	transportation	transportation_railroads.mdb	railroad_centerline	Research and Innovative Technology Administration's Bureau of Transportation Statistics (RITA-BTS)
Base Map	Transportation Infrastructure/Major Road	X	X	X	transportation	transportation_roads.mdb	road_centerline_ntad_nhpn	Research and Innovative Technology Administration's Bureau of Transportation Statistics (RITA-BTS)
Base Map	Transportation Infrastructure/Port	X	X	X	transportation	transportation_water.mdb	transportation_ports	Research and Innovative Technology Administration's Bureau of Transportation Statistics (RITA-BTS)
Base Map	Transportation Infrastructure/Railroad	X			transportation	transportation_roads.mdb	hazardous_material_routes	Research and Innovative Technology Administration's Bureau of Transportation Statistics (RITA-BTS)
Base Map	U.S. Census Tract	X	X	X	demographics	demographics.mdb	census_tract_area	United States Census Bureau
Base Map	Urban Area	X	X	X	demographics	demographics.mdb	urban_area	Environmental Systems Research Institute (ESRI)
Base Map/Public Land Survey System	Section	X	X		cadastre	plss_township_section.mdb	township_section_area	Bureau of Land Management (BLM)

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Base Map/Public Land Survey System	Township	X	X		cadastre	plss_township_range.mdb	township_range_area	Bureau of Land Management (BLM)
Biomass Resources	Biomass Assessment (NREL) (2005)	X			flora	flora.mdb	land_vegetation_area_biomass	National Renewable Energy Laboratory (NREL)
Biomass Resources	Conventional Crops	X			flora	flora.mdb	biomass_KDF_Crop_BLYE C1BLT_2012	Bioenergy Knowledge Discovery Framework (KDF), U.S. Department of Energy (DOE), Oak Ridge National Laboratory (ORNL)
Biomass Resources	Conventional Crops	X			flora	flora.mdb	biomass_KDF_Crop_BLYE C1BLT_2022	Bioenergy Knowledge Discovery Framework (KDF), U.S. Department of Energy (DOE), Oak Ridge National Laboratory (ORNL)
Biomass Resources	Energy Crops/Crop Residues	X			flora	flora.mdb	biomass_KDF_Agri_BLYEC 1BLT_2012	Bioenergy Knowledge Discovery Framework (KDF), U.S. Department of Energy (DOE), Oak Ridge National Laboratory (ORNL)
Biomass Resources	Energy Crops/Crop Residues	X			flora	flora.mdb	biomass_KDF_Agri_BLYEC 1BLT_2022	Bioenergy Knowledge Discovery Framework (KDF), U.S. Department of Energy (DOE), Oak Ridge National Laboratory (ORNL)
Biomass Resources	Forested Area		X		flora	flora.mdb	land_vegetation_area	State of Alaska Division of Forestry
Biomass Resources	Secondary Agriculture Residue	X			flora	flora.mdb	biomass_KDF_Agri_SCND_2012	Bioenergy Knowledge Discovery Framework (KDF), U.S. Department of Energy (DOE), Oak Ridge National Laboratory (ORNL)

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Biomass Resources	Secondary Agriculture Residue	X			flora	flora.mdb	biomass_KDF_Agri_SCND_2022	Bioenergy Knowledge Discovery Framework (KDF), U.S. Department of Energy (DOE), Oak Ridge National Laboratory (ORNL)
Biomass Resources	Secondary Forest Residue	X			flora	flora.mdb	biomass_KDF_Frst_SCND_2012	Bioenergy Knowledge Discovery Framework (KDF), U.S. Department of Energy (DOE), Oak Ridge National Laboratory (ORNL)
Biomass Resources	Secondary Forest Residue	X			flora	flora.mdb	biomass_KDF_Frst_SCND_2022	Bioenergy Knowledge Discovery Framework (KDF), U.S. Department of Energy (DOE), Oak Ridge National Laboratory (ORNL)
Communications	Air Route Surveillance Radar (ARSR)	X		X	communications	Communications_equipment.mdb	radar_site_arsr	Renewable Energy and Defense Geospatial Database (READ-Database), Air Defense Radar Site Search
Communications	Airport Surveillance Radar (ASR)	X	X	X	communications	Communications_equipment.mdb	radar_site_asr	Renewable Energy and Defense Geospatial Database (READ-Database), National Oceanic and Atmospheric Administration-National Geodetic Survey, the Federal Aviation Administration-U.S. & Territories Airport Lookup

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Communications	Alaska Radar System (ARS)		X		communications	Communications_equipment.mdb	radar_site_ars	Renewable Energy and Defense Geospatial Database (READ-Database), Radomes, Inc.-Air Defense Radar Site Search
Communications	FAA Ten Mile Circles	X	X	X	communications	Communications_equipment.mdb	radar_site_10_mile_buff	National Oceanic and Atmospheric Administration (NOAA)
Communications	Next-Generation Radar Weather Radar (NEXRAD)	X	X	X	communications	Communications_equipment.mdb	radar_site_nexrad	Renewable Energy and Defense Geospatial Database (READ-Database), National Oceanic and Atmospheric Administration-National Climatic Data Center Weather and Climate Toolkit
Communications	Terminal Doppler Weather Radar (TDWR)	X			communications	Communications_equipment.mdb	radar_site_tdwr	Renewable Energy and Defense Geospatial Database (READ-Database), National Oceanic and Atmospheric Administration-National Climatic Data Center Weather and Climate Toolkit
Communications	Tethered Aerostat Radar System (TARS)	X			communications	Communications_equipment.mdb	radar_site_tars	Renewable Energy and Defense Geospatial Database (READ-Database), United States Air Force –U.S. Department of Defense
Communications	WSR-88D RADAR Line of Sight	X	X	X	communications	Communications_equipment.mdb	radar_site_line_of_sight	National Oceanic and Atmospheric Administration (NOAA)

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Communications	WSR-88D RADAR Location	X	X	X	communications	Communications_equipment.mdb	radar_site	National Oceanic and Atmospheric Administration (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 copy supplied
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 National Laboratory (Argonne), U.S. Department of Energy (DOE)
Energy Corridor	Section 368 Centerline w/ Designation	X			land_status	wwec.mdb	developable_area_section368_centerline_eis	Argonne National Laboratory (Argonne)
Energy Corridor	Section 368 Centerline w/ Designation	X			land_status	wwec.mdb	sec368centerline_atts	Argonne National Laboratory (Argonne)
Energy Corridor	Section 368 Centerline w/ Mode	X			land_status	wwec.mdb	developable_area_section368_centerline_eis	Argonne National Laboratory (Argonne)
Energy Corridor	Section 368 Centerline w/ Mode	X			land_status	wwec.mdb	sec368centerline_atts	Argonne National Laboratory (Argonne)
Energy Corridor	Section 368 Zone w/ Designation	X			land_status	wwec.mdb	developable_area_section368_zone_eis	Argonne National Laboratory (Argonne)
Energy Corridor	Section 368 Zone w/ Designation	X			land_status	wwec.mdb	sec368zone_atts	Argonne National Laboratory (Argonne)

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Energy Corridor	Section 368 Zone w/ Mode	X			land_status	wwec.mdb	developable_area_section368_zone_eis	Argonne National Laboratory (Argonne)
Energy Corridor	Section 368 Zone w/ Mode	X			land_status	wwec.mdb	sec368zone_atts	Argonne National Laboratory (Argonne)
Existing Energy Infrastructure	Alternative Fuel Station	X	X	X	transportation	transportation_fuel.mdb	alternative_fuels_stations_sites	Research and Innovative Technology Administration's Bureau of Transportation Statistics (RITA-BTS)
Existing Energy Infrastructure	Commercial Nuclear Power Plant	X			utilities	utilities.mdb	nuclear_power_plant_site_unique	International Atomic Energy Agency, National Research Council, and others.
Existing Energy Infrastructure	CSP Plant Location	X			utilities	utilities.mdb	csp_plant_location	National Renewable Energy Laboratory (NREL)
Existing Energy Infrastructure	Electrical Transmission Line (Alaska)		X		utilities	utilities.mdb	electrical_cable_line_alaska	Alaska State Geo-spatial Data Clearinghouse (ASGDC)
Existing Energy Infrastructure	Electrical Transmission Line (FEMA)	X			utilities	utilities.mdb	electrical_cable_line_fema	National Renewable Energy Laboratory (NREL)
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	Alaska State Geo-spatial Data Clearinghouse (ASGDC)
Existing Energy Infrastructure	TVA Fossil Power Plant	X			utilities	utilities.mdb	fossil_power_plant_site_TV A	Argonne National Laboratory (Argonne)
Existing Energy Infrastructure	TVA Nuclear Power Plant	X			utilities	utilities.mdb	nuclear_power_plant_site_TVA	Argonne National Laboratory (Argonne)
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

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
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_morphologic_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_10pct50yr	United States Geological Survey (USGS)
Geology	Seismic Risk/Points: Peak Horizontal Acceleration With 10% Probability of Exceedance in 50 Years	X			geology	geology_tectonic.mdb	seismic_risk_point_10pct50yr	United States Geological Survey (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	Environmental Systems Research Institute (ESRI)
Geology	Volcano		X		geology	geology.mdb	volcano_site	Alaska Volcano Observatory, United States Geological Survey (USGS), Geophysical Institute of the University of Alaska Fairbanks (UAFGI), State of Alaska Division of Geological and Geophysical Surveys (ADGGS)

Table 6.1 (Cont.)

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	EGS Potential	X			geology	geology.mdb	geothermal_egs_potential	National Renewable Energy Laboratory (NREL)
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_favorability_sites	United States Geological Survey (USGS)
Geothermal Resources	Geothermal Potential Area	X	X		geology	geology.mdb	geothermal_potential_area	Bureau of Land Management (BLM)
Geothermal Resources	Geothermal Potential Area		X		geology	geology.mdb	potential_geothermal_resources	Alaska Energy Data Inventory (AEDI)
Geothermal Resources	Geothermal Project	X			geology	geology.mdb	wrez_geothermal_resources_projects	National Renewable Energy Laboratory (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	Idaho National Laboratory (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	Alaska Energy Data Inventory (AEDI)
Government Agency Boundary	BLM Administration Sites	X	X		buildings	buildings.mdb	blm_federal_structure_site	Bureau of Land Management (BLM)
Government Agency Boundary	BLM District Boundary	X	X		boundary	boundary.mdb	district_area_blm_district_admin	Bureau of Land Management (BLM)
Government Agency Boundary	BLM Field Offices and Resource Areas	X	X		boundary	boundary.mdb	district_area_blm_for_admin	Bureau of Land Management (BLM)
Government Agency Boundary	BLM Grazing Allotment	X			land_status	land_status.mdb	land_management_zone_area_blm_grazing	Bureau of Land Management (BLM)

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Government Agency Boundary	BLM Range Allotment Pasture	X			land_status	land_status.mdb	land_management_zone_area_blm_pasture	Bureau of Land Management (BLM)
Government Agency Boundary	BLM State Jurisdiction Boundary	X	X		boundary	boundary.mdb	district_area_blm_state_admin	Bureau of Land Management (BLM)
Government Agency Boundary	Federal Government Administered Land	X	X	X	cadastre	cadastre.mdb	agency_owned_area_anl_090914	Bureau of Land Management - National Landscape Conservation System (BLM - NLCS)
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	Bureau of Land Management (BLM)
Government Agency Boundary	FWS Administration Sites	X	X	X	buildings	buildings.mdb	fws_federal_structure_site	U.S. Fish and Wildlife Service (FWS)
Government Agency Boundary	State Administered Land	X	X		cadastre	cadastre.mdb	agency_owned_area_state_080924	Bureau of Land Management-National Landscape Conservation System (BLM-NLCS)
Government Agency Boundary	Tribal Corporation		X		cadastre	cadastre.mdb	alaska_tribal_corporations	Alaska State Geo-spatial Data Clearinghouse (ASGDC)
Government Agency Boundary	Tribal Land	X	X	X	cadastre	cadastre.mdb	agency_owned_area_tribal	United States Census Bureau
Government Agency Boundary	U.S. Forest Service Ranger District	X	X		boundary	boundary.mdb	district_area_fs_ranger_dist	U.S. Forest Service (USFS)
Government Agency Boundary	U.S. Forest Service Region	X	X	X	boundary	boundary.mdb	district_area_fs_region	U.S. Forest Service (USFS)
Government Agency Boundary	U.S. General Services Administration Region	X	X		boundary	boundary.mdb	district_area_gsa_region	Environmental Systems Research Institute (ESRI), U.S. General Services Administration (GSA), Argonne National Laboratory (Argonne)

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Government Agency Boundary	USFS Range Allotment	X			land_status	land_status.mdb	land_management_zone_area_usfs	Bureau of Land Management (BLM)
Hydrogen Resources	Hydrogen Potential from Resources	X	X	X	climate	climate_hydrogen.mdb	energy_potential_hydrogen	National Renewable Energy Laboratory (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
Hydrography	Energy Potential - Non-Powered Dam (ORNL)	X			improvement	improvement_flood_control.mdb	energy_potential_non_powered_dam_site	Oak Ridge National Laboratory (ORNL)
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			hydrography	hydrography.mdb	hydrologic_units	United States Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS)
Hydrography	Hydrologic Unit		X		hydrography	hydrography.mdb	hydrologic_units	United States Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS)
Hydrography	Hydrologic Unit			X	hydrography	hydrography.mdb	hydrologic_units	United States Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS)

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Hydrography	Navigable Waterway Network	X	x	x	hydrography	hydrography.mdb	navigable_waterway_network	Research and Innovative Technology Administration's Bureau of Transportation Statistics (RITA-BTS)
Hydrography	Pump Storage	X			hydrography	hydrography.mdb	pump_storage_site	Argonne National Laboratory (Argonne)
Hydrography	Stream / River	X	X	X	hydrography	hydrography.mdb	surface_water_course_centerline	Environmental Systems Research Institute (ESRI)
Hydrography	TVA Reservoir	X			hydrography	hydrography.mdb	reservoir_management_area_TVA	Argonne National Laboratory (Argonne)
Hydrography	Water Body	X	X	X	hydrography	hydrography.mdb	surface_water_body_area	Environmental Systems Research Institute (ESRI)
Hydropower Resources	Hydropower Potential Reach (Idaho National Laboratory)	X	X	X	hydrography	hydrography.mdb	surface_water_course_centerline_inl_study	Idaho National Laboratory (INL)
Hydropower Resources	Hydropower Potential Site (Idaho National Laboratory)	X	X	X	hydrography	hydrography.mdb	surface_water_course_point_inl_study	Idaho National Laboratory (INL)
Hydropower Resources	Hydropower Resource	X			hydrography	hydrography.mdb	wrez_hydro_resources	National Renewable Energy Laboratory-Western Renewable Energy Zones (NREL-WREZ)
Hydropower Resources	Significant Wave Height Group				hydrography	hydrography.mdb	wave_significant_height	National Renewable Energy Laboratory (NREL), Electric Power Research Institute (EPRI), Virginia Polytechnic Institute and State University (Virginia Tech)

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Hydropower Resources	Wave Energy Period Group				hydrography	hydrography.mdb	wave_energy_period	National Renewable Energy Laboratory (NREL), Electric Power Research Institute (EPRI), Virginia Polytechnic Institute and State University (Virginia Tech)
Hydropower Resources	Wave Hindcast Direction Group				hydrography	hydrography.mdb	wave_hindcast_direction	National Renewable Energy Laboratory (NREL), Electric Power Research Institute (EPRI), Virginia Polytechnic Institute and State University (Virginia Tech)
Hydropower Resources	Wave Power Density Group				hydrography	hydrography.mdb	wave_power_density	National Renewable Energy Laboratory (NREL), Electric Power Research Institute (EPRI), Virginia Polytechnic Institute and State University (Virginia Tech)
Hydropower Resources	Wave Study Depth				hydrography	hydrography.mdb	wave_depth	National Renewable Energy Laboratory (NREL), Electric Power Research Institute (EPRI), Virginia Polytechnic Institute and State University (Virginia Tech)
Methane Resources	TVA Green Power Switch® Methane Site	X			utilities	utilities.mdb	green_power_switch_methane_site_TVA	Argonne National Laboratory (Argonne)

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Other Energy Resources	Coal Basin, Region or Field	X	X		geology	geology.mdb	coal_basin_regions_fields	U.S. Department of Energy-Energy Information Administration (DOE-EIA)
Other Energy Resources	Coal Bed CO2 Storage Suitability	X	X		geology	geology.mdb	coalbed_formation_suitability	National Energy Technology Laboratory (NETL)
Other Energy Resources	Coalbed Methane Field	X	X		geology	geology.mdb	coalbed_methane_fields	U.S. Department of Energy-Energy Information Administration (DOE-EIA)
Other Energy Resources	EPA Renewable Energy Sites	X	X	X	environmental_hazards	environmental_hazards.mdb	epa_renewable_energy_site	U.S. Environmental Protection Agency (EPA), Office of Solid Waste and Emergency Response, Center for Program Analysis, National Renewable Energy Laboratory
Other Energy Resources	Mineral Resource	X	X	X	land_status	land_status.mdb	mine_site	United States Geological Survey (USGS)
Other Energy Resources	North American CO2 Source	X	X	X	environmental_hazards	environmental_hazards.mdb	co2_sources	National Energy Technology Laboratory (NETL)
Other Energy Resources	North American Oil & Gas Field	X	X		geology	geology.mdb	oil_and_gas_reservoirs	National Energy Technology Laboratory (NETL)
Other Energy Resources	North American Saline Basin	X	X		geology	geology.mdb	deep_saline_formations	National Energy Technology Laboratory (NETL)
Other Energy Resources	North American Saline Basin	X	X		geology	geology.mdb	deep_saline_formations_polygon	National Energy Technology Laboratory (NETL)
Other Energy Resources	Oil Shale Area	X			geology	geology.mdb	oil_shale_areas	Bureau of Land Management (BLM)

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Other Energy Resources	Oil Shale Closed Area	X			geology	geology.mdb	oil_shale_closed_areas	Bureau of Land Management (BLM)
Other Energy Resources	Oil Shale Prospective Area	X			geology	geology.mdb	oil_shale_prospective_areas	Bureau of Land Management (BLM)
Other Energy Resources	Shale Gas Basin	X			geology	geology.mdb	shale_gas_basins	U.S. Department of Energy-Energy Information Administration (DOE-EIA)
Other Energy Resources	Shale Gas Play, Stacked Shale Gas Play	X			geology	geology.mdb	shale_gas_plays	U.S. Department of Energy-Energy Information Administration (DOE-EIA)
Other Energy Resources	Unmineable Coal Seam	X	X		geology	geology.mdb	unmineable_coal_seams	National Energy Technology Laboratory (NETL)
Protected Areas	Approved Acquisition (FWS)	X	X	X	cadastre	cadastre.mdb	agency_owned_area_fws_approved_acquisition	U.S. Fish and Wildlife Service (FWS)
Protected Areas	Archaeology Site (point)	X	X	X	cultural	cultural.mdb	archaeology_site_point	Cultural Resources Subcommittee of the National Park Service (NPS) GIS Council
Protected Areas	Archaeology Site (polygon)	X	X	X	cultural	cultural.mdb	archaeology_site_polygon	Cultural Resources Subcommittee of the National Park Service (NPS) GIS Council
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	National Park Service (NPS)
Protected Areas	BLM National Conservation Area	X			land_status	land_status.mdb	land_restriction_area_blm_conservation_areas	Bureau of Land Management (BLM)
Protected Areas	Class I Area - NPS		X	X	visual	visual.mdb	visual_management_area_nps	National Park Service (NPS)
Protected Areas	Class I Area - Tribal	X			visual	visual.mdb	visual_management_area_tribal	U.S. Environmental Protection Agency (EPA)

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Protected Areas	Class I Area - USFS				visual	visual.mdb	visual_management_area_usfs	National Park Service (NPS)
Protected Areas	Class I Area - USFWS		X		visual	visual.mdb	visual_management_area_fws	National Park Service (NPS)
Protected Areas	Designated Wilderness by Agency	X			land_status	land_status.mdb	land_restriction_area_wilderness_anl4	Bureau of Land Management-National Landscape Conservation System (BLM-NLCS)
Protected Areas	Experimental Research Forest/Area	X			land_status	land_status.mdb	land_restriction_area_experimental_research_forest	United States Geological Survey (USGS), GAP Analysis Program, National Biological Information Infrastructure (NBII)
Protected Areas	FWS Critical Habitat Area	X	X	X	land_status	land_status.mdb	land_restriction_area_fws_critical_habitat	U.S. Fish and Wildlife Service (FWS)
Protected Areas	Grand Portage National Monument	X			hydrography	hydrography.mdb	surface_water_course_centerline_wsrns_mon	Wild & Scenic River System Organization
Protected Areas	Historic Building Site (point)	X	X	X	cultural	cultural.mdb	historic_building_site_point	Cultural Resources Subcommittee of the NPS GIS Council
Protected Areas	Historic Building Site (polygon)	X	X	X	cultural	cultural.mdb	historic_building_site_polygon	Cultural Resources Subcommittee of the NPS GIS Council
Protected Areas	Historic District Site (point)	X	X	X	cultural	cultural.mdb	historic_district_site_point	Cultural Resources Subcommittee of the NPS GIS Council
Protected Areas	Historic District Site (polygon)	X	X	X	cultural	cultural.mdb	historic_district_site_polygon	Cultural Resources Subcommittee of the NPS GIS Council
Protected Areas	Historic Object Site (point)	X	X	X	cultural	cultural.mdb	historic_object_site_point	Cultural Resources Subcommittee of the NPS GIS Council
Protected Areas	Historic Object Site (polygon)	X	X	X	cultural	cultural.mdb	historic_object_site_polygon	Cultural Resources Subcommittee of the NPS GIS Council

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Protected Areas	Historic Structure Site (point)	X	X	X	cultural	cultural.mdb	historic_structure_site_point	Cultural Resources Subcommittee of the NPS GIS Council
Protected Areas	Historic Structure Site (polygon)	X	X	X	cultural	cultural.mdb	historic_structure_site_polygon	Cultural Resources Subcommittee of the NPS GIS Council
Protected Areas	Interest Acquisition (FWS)	X	X	X	cadastre	cadastre.mdb	agency_owned_area_fws_interest_boundary	U.S. Fish and Wildlife Service (FWS)
Protected Areas	Military Special Use Airspace (DOD)	X	X	X	military_operations	military_operations.mdb	special_use_airspace_site	SRS Technologies
Protected Areas	Military Training Route (DOD)/MTR - Instrument Corridor	X	X	X	military_operations	military_operations.mdb	military_flight_corridor_area_ir	SRS Technologies
Protected Areas	Military Training Route (DOD)/MTR - Low-level Corridor	X	X	X	military_operations	military_operations.mdb	military_flight_corridor_area_sr	SRS Technologies
Protected Areas	Military Training Route (DOD)/MTR - Visual Corridor	X	X	X	military_operations	military_operations.mdb	military_flight_corridor_area_vr	SRS Technologies
Protected Areas	Military Training Route (DOD)/MTR Centerline	X	X	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	Bureau of Land Management-National Landscape Conservation System (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 (NPS)
Protected Areas	National Park Service Property	X	X	X	improvement	improvement_recreation.mdb	recreation_park_area	National Park Service (NPS)
Protected Areas	National Parkway	X			transportation	transportation_roads.mdb	road_centerline_nlcs_national_parkway	Wild & Scenic River System Organization
Protected Areas	National Recreation Area (BLM)	X			land_status	land_status.mdb	land_restriction_area_blm_national_recreation_areas	Bureau of Land Management (BLM)
Protected Areas	National Recreation Area (NPS)	X			land_status	land_status.mdb	land_restriction_area_nps_national_recreation_areas	National Park Service (NPS)

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Protected Areas	National Recreation Area (USFS)	X			land_status	land_status.mdb	land_restriction_area_usfs_national_recreation_areas	Bureau of Land Management (BLM)
Protected Areas	National Scenic or Backcountry Byway	X	X	X	visual	visual.mdb	scenic_backcountry_byways	National Scenic Byway Organization (NSBO)
Protected Areas	National Trail	X	X		improvement	improvement_recreation.mdb	recreation_trail_centerline	Argonne National Laboratory (Argonne)
Protected Areas	National Trail (FWS)	X	X	X	improvement	improvement_recreation.mdb	recreation_trail_centerline_fws	U.S. Fish and Wildlife Service (FWS)
Protected Areas	National Wildlife Refuge	X	X	X	cadastre	cadastre.mdb	agency_owned_area_fws_refuge	U.S. Fish and Wildlife Service (FWS)
Protected Areas	Protected Areas Database	X	X	X	land_status	protected_areas_database.mdb	land_restriction_protected_areas_database	United States Geological Survey (USGS), GAP Analysis Program, National Biological Information Infrastructure (NBII)
Protected Areas	Research Natural Areas	X			land_status	land_status.mdb	land_restriction_area_research_natural_area	United States Geological Survey (USGS), GAP Analysis Program, National Biological Information Infrastructure (NBII)
Protected Areas	Special Designation (FWS)	X	X	X	land_status	land_status.mdb	land_restriction_area_fws_special_designation	U.S. Fish and Wildlife Service (FWS)
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 (USFS)
Protected Areas	USFS Specially Designated Area	X	X		land_status	land_status.mdb	land_restriction_area_usfs_sda	U.S. Forest Service (USFS)
Protected Areas	Wild and Scenic River (WSRS)		X		hydrography	hydrography.mdb	surface_water_course_centerline_nlcs_wsr	Bureau of Land Management-National Landscape Conservation System (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

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Protected Areas	Wilderness Area	X	X	X	land_status	land_status.mdb	land_restriction_area_wilderness	University of Montana's Wilderness Institute, U.S. Fish and Wildlife Service (FWS), Bureau of Land Management (BLM), National Park Service (NPS), U.S. Forest Service (USFS)
Protected Areas	Wilderness Study Area (BLM)	X			land_status	land_status.mdb	land_restriction_area_wsa_anl2	Bureau of Land Management-National Landscape Conservation System (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	U.S. Environmental Protection Agency (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	U.S. Army Corps of Engineers (USACE)
Protected Areas/National Ambient Area Air Quality Standard Area	NAAQS Area - Carbon Monoxide	X			environmental_hazards	env_haz_air_pollution.mdb	air_pollution_nonattainment_area_co	U.S. Environmental Protection Agency (EPA)
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	U.S. Environmental Protection Agency (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	U.S. Environmental Protection Agency (EPA)

Table 6.1 (Cont.)

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 - Ozone - 1-hour	X			environmental_hazards	env_haz_air_pollution.mdb	air_pollution_nonattainment_area_o3_1hour	U.S. Environmental Protection Agency (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	U.S. Environmental Protection Agency (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	U.S. Environmental Protection Agency (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	U.S. Environmental Protection Agency (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	U.S. Environmental Protection Agency (EPA)
Solar Resources	Concentrating Solar Power (Direct Normal) (NREL)	X		X	climate	climate_solar.mdb	energy_potential_solar_csp	National Renewable Energy Laboratory (NREL)
Solar Resources	Concentrating Solar Power (Direct Normal) (NREL) 40 km.		X		climate	climate_solar.mdb	energy_potential_solar_csp	National Renewable Energy Laboratory (NREL)
Solar Resources	Concentrating Solar Power (Direct Normal) Potential	X			climate	climate_solar.mdb	energy_potential_solar_conc	National Renewable Energy Laboratory (NREL)
Solar Resources	Concentrating Solar Prospects SW U.S./Slope Filter Less than 1%	X			climate	climate_solar2.mdb	csp_southwest_filter_1percent	National Renewable Energy Laboratory (NREL)

Table 6.1 (Cont.)

ArcReader Group	ArcReader Layer Name	Contiguous	Alaska	Hawaii	Data Directory Name	Filename	Feature Class Name	Source Organization
Solar Resources	Concentrating Solar Prospects SW U.S./Slope Filter Less than 2%	X			climate	climate_solar2.mdb	csp_southwest_filter_2percent	National Renewable Energy Laboratory (NREL)
Solar Resources	Concentrating Solar Prospects SW U.S./Slope Filter Less than 3%	X			climate	climate_solar2.mdb	csp_southwest_filter_3percent	National Renewable Energy Laboratory (NREL)
Solar Resources	Concentrating Solar Prospects SW U.S./Slope Filter Less than 4%	X			climate	climate_solar2.mdb	csp_southwest_filter_4percent	National Renewable Energy Laboratory (NREL)
Solar Resources	Concentrating Solar Prospects SW U.S./Slope Filter Less than 5%	X			climate	climate_solar.mdb	csp_southwest_filter_5percent	National Renewable Energy Laboratory (NREL)
Solar Resources	Photovoltaic Potential	X		X	climate	climate_solar.mdb	energy_potential_solar_pv	National Renewable Energy Laboratory (NREL)
Solar Resources	Tilted Photovoltaic Potential	X		X	climate	climate_solar.mdb	energy_potential_solar_pvtilt	National Renewable Energy Laboratory (NREL)
Solar Resources	Tilted Photovoltaic Potential 40 km.		X		climate	climate_solar.mdb	energy_potential_solar_pvtilt	National Renewable Energy Laboratory (NREL)
Solar Resources	TVA Green Power Switch® Solar Site	X			utilities	utilities.mdb	green_power_switch_solar_site_TVA	Argonne National Laboratory (Argonne)
Wind Resources	Installed Wind Energy Capacity	X			utilities	utilities.mdb	installed_wind_energy_capacity	American Wind Energy Association (AWEA)
Wind Resources	NREL National Wind Resource Assessment (High Res)	X			climate	climate_wind2.mdb	energy_potential_wind_highres	National Renewable Energy Laboratory (NREL)
Wind Resources	NREL National Wind Resource Assessment (Low Res)	X	X	X	climate	climate_wind.mdb	energy_potential_wind_lowres	National Renewable Energy Laboratory (NREL)
Wind Resources	Offshore Wind Resources (NREL, 90 m)	X			climate	climate_wind2.mdb	offshore_energy_potential_wind	National Renewable Energy Laboratory (NREL)

Table 6.1 (Cont.)

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		X	climate	climate_wind.mdb	offshore_potential_wind_atlantic, pacific, gulf_mexico, great_lakes, hawaii	National Renewable Energy Laboratory (NREL)
Wind Resources	TVA Green Power Switch® Wind Site	X			utilities	utilities.mdb	green_power_switch_wind_site_TVA	Argonne National Laboratory (Argonne)
Wind Resources	Wind Resources by State (NREL, 50 m)	X	X	X	climate	climate_wind.mdb	energy_potential_wind_ia, nd, sd, sc, mn, mt, ne, ar, ga, il, in, ks, ky, mi, mid atlantic, mn, mo, mt, new england, oh, ok, prvi, ca, pacific northwest, az, nv, ny, ut, co, nm, hi, ak, tn, tx, wi	National Renewable Energy Laboratory (NREL)
Wind Resources	Wind Turbine (FAA)	X	X	X	improvement	improvement_machinery.mdb	windmill_windmotor_site	Federal Aviation Administration

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