

**Data Guidelines for
“Renewable Energy Generation Potential on EPA and State Tracked Sites” Maps
Produced by EPA OSWER Center for Program Analysis**

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OVERVIEW

The U.S. Environmental Protection Agency (EPA) Office of Solid Waste and Emergency Response (OSWER) Center for Program Analysis (CPA) initiated the RE-Powering America’s Land Initiative to demonstrate the enormous potential that contaminated land and mine sites provide for developing renewable energy in the United States. EPA developed national level site screening criteria in partnership with the U.S. Department of Energy (DOE) National Renewable Energy Laboratory (NREL) for wind, solar, biomass and geothermal facilities. While the screening criteria demonstrate the potential to reuse contaminated land for renewable energy facilities, the criteria and the maps are not designed to identify the best sites for developing renewable energy and are not all-inclusive. More detailed, site-specific analysis is necessary to identify or prioritize the best sites for developing renewable energy facilities based on technical and economic potential.

BACKGROUND

According to the U.S. Energy Information Administration’s *Annual Energy Outlook 2008*, by 2030 U.S. electricity production will need to increase by nearly 30% to meet growing demand.¹ In 2007, wind, solar, biomass and geothermal supplied 2.9% of the nation’s electricity.² While these renewable sources currently make up only a fraction of energy production, renewable energy production is expected to increase by more than 70% between 2006 and 2030.³ Identifying and using land located in areas with high quality renewable energy resources will be an essential component of developing more electricity from renewable energy sources.

However, these renewable energy facilities can require a large amount of land. An average solar plant requires five to 10 acres for every megawatt (MW) of generating capacity; a 200 MW solar plant in West Texas would need approximately 1,300 acres of land.⁴ As a result, two major questions are raised. Where can these new renewable energy facilities be built? What will the demands be on greenfields or previously undeveloped land?

Reusing contaminated land and mine sites may provide the answers to these questions. Over time, millions of acres across the country have been damaged by varying levels of pollution. EPA alone tracks nearly 490,000

¹ U.S. Department of Energy, Energy Information Administration. *Annual Energy Outlook 2008*. Table A8: Electricity Supply, Disposition, Prices, and Emissions. Available at: www.eia.doe.gov/oiaf/aeo/pdf/appa.pdf

² U.S. Department of Energy, Energy Information Administration. Renewable and Alternative Fuel, Table 4: 2007 U.S. Electric Net Summer Capacity. Available at: www.eia.doe.gov/cneaf/alternate/page/renew_energy_consump/table4.html

³ U.S. Department of Energy, Energy Information Administration. *Annual Energy Outlook 2008*. Table A8: Electricity Supply, Disposition, Prices, and Emissions. Available at: www.eia.doe.gov/oiaf/aeo/pdf/appa.pdf

⁴ SECO. *Texas Solar Energy: Land and Water Needs for Solar Power*. Texas State Energy Conservation Office. Available at: http://www.seco.cpa.state.tx.us/re_solar.htm

sites and almost 15 million acres of potentially contaminated or contaminated properties. Over the last decade, all levels of government have implemented policies to revitalize these properties for community, ecologic and economic uses. In many places, government, private and non-profit organizations work with each other to assess, clean up and return unproductive properties to sustainable and beneficial uses that are protective of health and the environment. To date, more than 917,000 acres of EPA tracked land achieved cleanup goals and have controls in place to ensure long-term protection.

Contaminated land and mine sites may be appropriate to site some of the new renewable energy facilities projected to be built in the next 25 years. While many of these sites will require cleanup action and monitoring, there are opportunities for and benefits to reusing this land. The advantages to siting renewable energy on contaminated land and mine sites may include: critical infrastructure including transmission lines, roads and water onsite; appropriate zoning already in place; the availability of large sites with few site owners; reduced local opposition to renewable energy development; and the availability of many government programs that support cleanup and reuse. In addition, reusing these sites prevents the development of greenfield sites which serve as a critical carbon sink, protect watersheds and wetlands, provide habitat, and provide raw resources. Renewable energy is also an economically viable reuse for sites with significant cleanup costs or low real estate development demand, and can provide job opportunities in urban and rural communities, particularly where factories, mining and other manufacturing activities have ceased operations.

In order to demonstrate the potential that contaminated land provides for developing renewable energy in the United States, EPA initiated the *RE-Powering America's Land: Siting Renewable Energy on Potentially Contaminated Land and Mine Sites* initiative. This initiative educates the private sector, all levels of government and communities about the benefits of siting renewable energy on contaminated land instead of undeveloped greenfield land. EPA developed tools to help stakeholders understand the enormous potential of contaminated land for siting renewable energy facilities including geographic information system (GIS)-based maps, a Google Earth interactive map, and an associated Excel data spreadsheet and GIS shapefile. These resources demonstrate that a large number of EPA and state tracked sites meet basic renewable energy siting criteria. To generate these maps, EPA developed national level site screening criteria in partnership with NREL. The criteria are intended to provide a rough estimate of how much of the projected renewable energy needs in the United States could be met by siting these facilities on contaminated land.

While the screening criteria indicates which sites may have potential for renewable energy development, the criteria and the maps are not designed to identify the best sites for developing renewable energy and are not all-inclusive. There are some sites shown on the maps that may not be suitable for siting renewable energy based on further site-specific analysis; in addition, some viable sites may not be included on these maps due to the screening criteria used. For example, additional sites could have potential for geothermal flash or binary power plants in areas where there are greater depths coupled with higher temperatures.

All sites have unique variables that affect their feasibility (e.g., market conditions such as renewable energy portfolio standards and physical attributes of a site). For example, EPA and state tracked sites included in these maps are at varying points in the cleanup process, with some sites being ready for reuse and others requiring cleanup. Therefore, more detailed site-specific analysis is necessary to identify or prioritize the best sites for developing renewable energy facilities based on technical and economic potential. Future projects to identify the best sites for renewable energy development may be conducted by individual cleanup programs, EPA Regions or other partnerships (e.g., public-private partnerships). It should also be noted that EPA and state tracked data are updated continuously; the maps and data provide a snapshot in time and will be updated periodically.

Through the *RE-Powering America's Land* initiative, EPA seeks to educate stakeholders about the land use demands posed by renewable energy development and the viability of contaminated sites for renewable energy generation to prevent the development of greenfields.

RENEWABLE ENERGY TECHNOLOGIES EVALUATED

The following renewable energy technologies were evaluated for this analysis. They represent the most widespread types of renewable energy facilities being used today. This is not an inclusive list of all renewable energy technologies; new technologies continue to be developed while established technologies are refined. For information on how each renewable energy type was evaluated, please refer to the Screening Criteria section below.

Solar

Solar technologies generate electricity from the sun's energy. The two types of solar technologies evaluated, concentrating solar power and photovoltaic, are described below. For more information on solar technologies, visit: http://www.nrel.gov/learning/re_solar.html.

Utility scale concentrating solar power (CSP): Uses the sun's thermal energy to heat a liquid that drives a generator to produce electricity. CSP technology is constructed at the megawatt or multi-megawatt scale and electricity generated is typically exported to the grid. Three types of utility scale CSP technologies were evaluated by EPA:

- Trough system: Collects the sun's thermal energy using long rectangular, curved (U-shaped) mirrors. The mirrors are tilted toward the sun, focusing sunlight on tubes that run the length of the mirrors. The reflected sunlight heats a fluid flowing through the tubes. The hot fluid then is used to boil water in a conventional steam-turbine generator to produce electricity.
- Power tower system: Uses a large field of flat, sun-tracking mirrors known as heliostats to focus and concentrate sunlight onto a receiver on the top of a tower. A heat-transfer fluid heated in the receiver is used to generate steam for a conventional steam-turbine generator to produce electricity. Some power towers use water/steam as the heat-transfer fluid, others use alternative materials such as molten salt.
- Stirling engine system: Uses a mirrored dish to direct and concentrate sunlight onto a thermal receiver. A fluid heated inside the receiver moves pistons and creates mechanical power, which runs the Stirling engine to produce electricity.

Photovoltaic (PV): Converts the sun's light energy directly into electricity. PV technology is scalable; the amount of electricity generated is directly related to the number and efficiency of installed panels. It can technically be sited anywhere, though the economics may make a project unfeasible in lower resource areas. Three types of PV production were evaluated by EPA:

- Utility scale PV: Uses PV technology at the megawatt or multi-megawatt scale at sites with the greatest resource and acreage availability. Electricity generated is typically exported to the grid.
- PV policy driven: Represents sites that may have development potential due to state policies, including sites in areas with lower resource availability. It includes states with a renewable portfolio standard (RPS) or RPS goal that have one or more of the following provisions: a solar set-aside that requires a certain percentage of the state's electricity be generated from solar resources; a solar multiplier that gives additional credit for solar projects that contribute toward meeting the RPS requirements; or a requirement for distributed generation (i.e., electricity generation close to the point of use). These incentives may help to make PV projects financially viable in areas with lower solar resource availability.
- Non-grid connected PV: This category represents PV technology being used at a smaller scale, typically to power the energy needs of a single property.

Wind

Wind energy is captured by wind turbines with propeller-like blades mounted on a tower. The force of the wind causes the rotor to spin and the turning shaft spins a turbine to generate electricity. Wind technology is scalable; based on site conditions, different turbines designs can be used to meet different electricity needs. For more information on wind technologies, visit: http://www.nrel.gov/learning/re_wind.html.

The following three types of wind production were evaluated by EPA:

- Utility scale: Uses large turbines at the megawatt or multi-megawatt scale on sites with the greatest resource and acreage availability. Electricity generated is typically exported to the grid.
- Community: Represents sites with less acreage than the utility scale wind sites, potentially using smaller or fewer turbines. Electricity generated is distributed to the local area through the distribution system, often serving only adjacent properties.
- Non-grid connected: Uses smaller and fewer turbines on a much smaller scale, typically to power the energy needs of a single property.

Biomass

Biomass energy or “bioenergy” is generated from organic feedstocks. Wood is the largest biomass energy resource; other sources of biomass include food crops, grassy and woody plants, residues from agriculture or forestry, and the organic component of municipal and industrial wastes. These feedstocks can be used as a solid fuel, or converted into liquid or gaseous forms, for the production of electric power, heat, chemicals or fuels. For more information on biomass technologies, visit: <http://www.nrel.gov/gis/biomass.html>. For more information on EPA's Landfill Methane Outreach Program (LMOP) and landfill gas energy technologies, visit <http://www.epa.gov/landfill/index.htm>.

The following three types of biomass production were evaluated by EPA:

- Biopower facility: Burns biomass resources to produce heat, which is used to boil water for a conventional steam-turbine generator to produce electricity. Biopower facilities utilize cumulative biomass resources that can include residues from: crops, forests, primary and secondary mills; urban wood waste; and methane emissions from manure management, landfills and domestic wastewater treatment.
- Biorefinery facility: Integrates biomass conversion processes and equipment to produce fuels, power, and chemicals from biomass. The technology utilizes cumulative crop residues that can include residues from crops, forests, primary and secondary mills and urban wood waste.
- Landfill gas energy project: Uses gas that is created as organic solid waste decomposes in a landfill. This gas consists mostly of methane (the primary component of natural gas) and carbon dioxide. Instead of allowing landfill gas to escape into the air, it is extracted from landfills using a series of wells and a blower/flare (or vacuum) system. The landfill gas is directed to a central point where it can be processed and treated to produce various forms of energy, including electricity, boiler fuel, steam, and alternate vehicle fuel and pipeline quality gas.

Geothermal

Geothermal facilities use heat stored in the earth to generate electricity. This heat comes from the original formation of the planet, radioactive decay of minerals, tectonic activity and solar energy absorbed at the surface. Geothermal facilities use heat from: hot water or steam reservoirs deep in the earth that are accessed by drilling; geothermal reservoirs located near the earth's surface, mostly located in western states, Alaska, and Hawaii; and the shallow ground near the Earth's surface that maintains a relatively constant temperature of 50°-60°F. For more information on geothermal technologies, visit the DOE Energy Efficiency and Renewable Energy (EERE) Geothermal Technologies Program at: <http://www1.eere.energy.gov/geothermal/> or http://www.nrel.gov/learning/re_geothermal.html.

The following three types of geothermal production were evaluated by EPA:

- Flash power plant: Uses geothermal reservoirs of water with very high temperatures that flow up through wells in the ground under its own pressure. As it flows upward, the pressure decreases and some of the hot water boils into steam. The steam is then separated from the water and used to power a turbine that generates electricity. Any leftover water and condensed steam are injected back into the reservoir, making this a sustainable resource.

- Binary power plant: Uses the heat from lower temperature geothermal resources to boil a working fluid, usually an organic compound with a low boiling point. The working fluid is vaporized in a heat exchanger and used to turn a turbine to generate electricity. The water is then injected via a closed-loop system back into the ground to be reheated in the geothermal reservoir. The water and the working fluid are kept separated during the whole process, so there are no air emissions.
- Geothermal heat pump: The upper 10 feet of the Earth maintains a nearly constant temperature between 50° and 60°F (10°-16°C). Geothermal heat pumps take advantage of this resource to heat and cool buildings and heat water. Geothermal heat pump systems consist of three parts: the ground loop heat exchanger, the heat pump unit, and the air delivery system (ductwork). The ground loop heat exchanger is a system of pipes which is buried in the shallow ground near the building or in a vertical well if land for a horizontal loop is limited. Water source heat pumps work on the same principle as ground-source systems, but use an adjacent body of water as the heat sink. A fluid (usually water or a mixture of water and antifreeze) circulates through the loop to absorb or relinquish heat within the ground. Geothermal heat pumps use much less energy than conventional heating systems, since they draw heat from the ground. Geothermal heat pumps typically serve a single property, though they may also be viable for use in multi-tenant applications such as integrated district heating systems.

MAPPING METHODOLOGY

EPA developed an inventory of abandoned mine lands, Brownfields program sites, Resource Conservation and Recovery Act (RCRA) sites, Superfund sites and landfills (see Datasets section for more detail). From this inventory, EPA extracted sites with acreage and viable latitude and longitude data. This subset of EPA and state tracked sites was then mapped against 14 different renewable energy types, as described in the screening criteria below.

Screening Criteria

The screening criteria below used to develop the renewable energy potential maps were approved by EPA and NREL. Although there are other critical factors for siting renewable energy facilities (e.g., slope), they were not considered in the mapping analysis. Please refer to the Data Considerations section for a description of screening criteria limitations.

Solar Resource Screening Criteria

Utility Concentrating Solar Power (CSP)	
Direct normal solar resource availability	≥6 kWh/m ² /day
Distance to transmission lines	≤10 miles
Acreage (Stirling engine system)	≥40
Acreage (trough and power tower system)	≥250
Distance to graded roads	≤25 miles

Utility Photovoltaic (PV) Solar	
Direct normal solar resource availability	≥5 kWh/m ² /day
Distance to transmission lines	≤10 miles
Acreage	≥40
Distance to graded roads	≤25 miles

PV Policy Driven	
Distance to transmission lines	≤10 miles
Acreage	≥40
Distance to graded roads	≤25 miles
In addition to the above screening criteria, these sites are located in states that have renewable portfolio standards (or goals) with one or more of the following provisions: solar set-aside; solar multiplier; or distributed generation	

Non-Grid Connected PV Solar	
There are no formal screening criteria as PV technology can be sited at all properties	

Wind Resource Screening Criteria

Utility Scale Wind	
Wind class, measured at 50 meters above ground	≥4
Distance to transmission lines	≤10 miles
Acreage	≥2,000
Distance to graded roads	≤25 miles

Community Wind	
Wind class, measured at 50 meters above ground	≥3
Distance to transmission lines	N/A
Acreage	100 - 1,999
Distance to graded roads	≤25 miles

Non-Grid Connected Wind	
Wind class, measured at 50 meters above ground	≥3

Biomass Screening Criteria

Biopower Facility	
Cumulative biomass resources	≥140,000 metric tons/year within 50 miles
Distance to transmission lines	≤10 miles
Acreage	≥50
Distance to graded roads	≤3 miles
Distance to rail	≤8 miles

Biorefinery Facility	
Cumulative crop residues	≥330,000 metric tons/year within 50 miles
Acreage	≥50
Distance to graded roads	≤3 miles
Distance to rail	≤8 miles

Landfill Gas Energy Project Screening Criteria

Landfill gas energy projects as defined by EPA's Landfill Methane Outreach Program (LMOP)
www.epa.gov/landfill

Candidate for Landfill Gas Energy (LFGE) Project
A landfill that is accepting waste or has been closed for five years or less, has at least one million tons of waste, and does not have an operational or under construction LFGE project; or is designated based on actual interest or planning

Potential for Landfill Gas Energy (LFGE) Project
A landfill that does not meet the candidate definition, whether because of complete or incomplete data. However, the landfill could have LFGE project potential based on site-specific needs or if data were complete.

Geothermal Screening Criteria

Geothermal Flash Power Plant	
Resource temperature	≥149°C (300°F)
Well depth	≤ 4.5 km
Distance to transmission lines	≤ 10 miles
Acreage	≥10 acres
Distance to graded roads	≤ 25 miles

Geothermal Binary Power Plant	
Resource temperature	≥ 93°C (200°F)
Well depth	≤ 3 km
Distance to transmission lines	≤10 miles
Acreage	≥ 10 acres
Distance to graded roads	≤ 25 miles

Geothermal Heat Pump
There are no formal screening criteria. All sites are generally considered favorable for geothermal heat pumps, though sites with near surface temperatures of 10°C (50°F) to 24°C (75°F) are generally preferred.

DATA CONSIDERATIONS

The following information should be considered when reviewing EPA's maps:

- EPA and state databases are updated continuously with information such as new sites and updated acreage. These maps provide a snapshot in time, as described in the datasets section. The use of site-specific information provided herein should only be used with the understanding that the information changes over time.
- EPA does not maintain or manage the West Virginia, Pennsylvania or Virginia datasets.

Location and Acreage Data

- EPA does not currently collect boundary data for its tracked sites; therefore, each EPA tracked site was mapped using a single latitude and longitude point obtained from EPA's official cleanup program databases (see Datasets section for more information on program-specific databases). In order to approximate the site size/boundary and estimate the total potential for renewable energy generation across an entire site, the site latitude and longitude point was mapped and a circular buffer was drawn around the site that was equal to the area reported for the site. The maximum and minimum renewable energy resource values that the buffer covered were recorded for solar and wind resources. For the biomass analysis, the screening criteria include resources within a 50-mile radius of the site. Therefore, a 50-mile buffer was drawn around the site and the sum of the biomass resource within 50 miles of the site was recorded. This methodology has limitations in that sites are typically not circles and latitude and longitude are not always recorded at the center of the site. However, given these limitations, this method will allow a more accurate snapshot of what energy potential may be available than the single data point.
- State tracked sites were provided as polygons in ESRI shapefile format, with the exception of Virginia Orphaned Mineral Mines. The polygon data provides a calculated acreage. The Virginia Orphaned Mineral Mines data were evaluated using the same methodology as was used for the EPA tracked sites (see preceding bullet and the Datasets section for more information).
- EPA and state tracked sites that were identified as having potentially incorrect latitude and longitude data (i.e., mapped five miles from the state as recorded or no coordinates were provided in EPA databases) are excluded from the maps.
- Since acreage is a key screening criterion, sites that do not have acreage information recorded in the databases are excluded from all maps except for the non-grid connected wind, non-grid connected PV solar and geothermal heat pump. Acreage is not a screening criterion for these maps because such systems are typically used to power a single property or local area, and are not constrained by limited acreage. For example, a property owner could install PV panels or "micro" small-scale wind turbines to supplement the electricity provided to the site from traditional sources, but would not typically generate power for export to the power grid.

Geographical Areas Not Mapped

- With the exception of Puerto Rico, the U.S. territories were not evaluated or included in this analysis as renewable energy resource and transmission data were not readily available for the U.S. territories.
- The transmission, rail and geothermal data used for this analysis did not include information for Alaska and Hawaii. The only maps that could be developed without this information are non-grid connected wind, community wind, non-grid connected PV solar and landfill gas energy.
- Biomass and geothermal resource data were not readily available for Puerto Rico. These renewable energy potential types were therefore not evaluated for Puerto Rico sites.

Photovoltaic Policy Driven and State Renewable Portfolio Standard (RPS) Notes

- State renewable energy policy information used to develop the PV policy driven maps is constantly changing and being updated. Please refer to the DOE Database of State Incentives for Renewables & Efficiency at <http://www.dsireusa.org/>.

Landfill Notes

- In general, the weight of wind turbines and CSP Stirling engine, trough and power tower systems and the drilling required for geothermal facilities makes it difficult to site these technologies directly on former landfills. Therefore, these technologies were not mapped for landfill sites. More detailed site research may show that there is potential for these types of technologies by siting on surrounding land or using other approaches.
- The mapped acreage for landfills is the highest acreage value among landfill designed area, landfill current area and landfill total area (see the Attributes Table for more information).

Geothermal Notes

- Geothermal resource data were obtained from Southern Methodist University in grid format and converted into raster images using Surfer 8.0 and ESRI ArcView 9.2. The raster data were then extracted to the site location points.
- Geothermal resource data was not available for some coastal sites due to the difficulty in overlaying resource maps with slightly different U.S. boundaries.
- For geothermal flash and binary plants, additional subsurface mineral rights covering adjacent acreage may be needed in order to capture enough of the resource to make development feasible. This is largely specific to the size of the power generating facility; the larger the size of the facility the more resource is needed for extraction of the hot liquid and its injection into the geothermal reservoir.
- Potential for geothermal direct use applications was not mapped because required temperature data at shallow depths were not available. In addition, there are numerous direct use applications (e.g., district space heating, crop drying, greenhouse heating and aquaculture), and each has its own specific temperature requirements. More information is available at: <http://www1.eere.energy.gov/geothermal/pdfs/directuse.pdf>.

Miscellaneous Notes

- In instances where distances to transmission lines, highways or rails are zero, the transmission line, highway or rail is intersecting the site buffer, meaning that the infrastructure is present within the generated site boundary.
- Although slope is a critical factor for siting some types of renewable energy, it was not considered in the mapping analysis due to limitations in the availability of high resolution slope data for sites dispersed across the United States. In addition, slope can vary dramatically across a site, especially at large sites (some EPA tracked sites measure upwards of 1,000 acres), making it difficult to accurately estimate each site's slope and the area of each site that would be suitable for each type of renewable energy. Site-specific slope analysis should be performed for any site being considered for renewable energy development.
- In order to identify EPA and state tracked sites located within each of the four identified Renewable Energy Zones (REZ) (see Datasets section below for more information), a buffer was drawn around the site based on reported site size and then the two datasets were joined to identify where the EPA tracked sites and the REZ overlapped.

DATASETS

The following data sources were used to develop the inventory of EPA and state tracked sites displayed on EPA's renewable energy potential maps. Note: EPA and state datasets are updated continuously so the maps provide a snapshot in time.

Abandoned Mine Lands (AML)

Includes all abandoned hardrock mines and mineral processing sites listed in the Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) as well as many AMLs with emergency response actions that are not listed in CERCLIS. AML data include information from the AML inventory dated February 27, 2008 and include CERCLIS information current as of January 2008. Acreage from the AML Inventory was used in most cases. In cases where acreage was not provided in the AML Inventory, CERCLIS acreage was used.

Brownfields

Includes data in the Assessment Cleanup and Redevelopment Exchange System (ACRES) database, queried on July 8, 2008. Data includes information on properties associated with Brownfields grants awarded in fiscal year 2003 and beyond, where an assessment or cleanup activity has been completed and EPA Brownfields funding was expended. This includes: Assessment, Cleanup, Revolving Loan Fund, Section 128 and Targeted Brownfields Assessment grants.

Resource Conservation and Recovery Act (RCRA)

Includes all sites from the RCRA 2020 Universe Inventory from July 2007. Acreage information was only provided for the 2008 Baseline Inventory sites, but site latitude and longitude information was provided for all sites.

Superfund

Includes Superfund sites included in the EPA OSWER Cross-Program Revitalization Measure (CPRM) universe, with information provided by the Superfund Office on July 24, 2008. Superfund site-specific information is available in CERCLIS.

Landfill Methane Outreach Program (LMOP)

Includes data from LMOP, which is a voluntary assistance and partnership program that promotes the use of landfill gas as a renewable, green energy resource. LMOP screens landfills to determine if they are candidates for landfill gas energy projects or have potential for landfill gas energy projects. In addition, it tracks landfills that have operational, under construction or shutdown landfill gas energy projects (see the Attribute Table for the definition of project types). Visit EPA's LMOP Web site at www.epa.gov/lmop/ for more information on landfill gas energy projects. This data were provided by LMOP on March 20, 2009.

State Tracked Abandoned Mine Lands and Orphaned Mineral Mines

The AMLs included in this analysis are coal mining sites that were operated prior to August 3, 1977. The enactment of Surface Mining Control and Reclamation Act (SMCRA) of 1977 created a fund to eliminate (reclaim) health and safety hazards associated with coal mining operations that were abandoned before the enactment of the statute. As a result of SMCRA, Pennsylvania, Virginia and West Virginia developed these datasets as inventories of AML sites eligible for reclamation.

The orphaned mineral mines included in this analysis are sites other than coal mines that were operated in Virginia prior to 1968, the enactment of the Virginia Reclamation Law. Once identified, an orphaned mine site is evaluated for its potential hazards to the environment and the public's health and safety. This includes soil and water investigations, studies on the feasibility of reclaiming the site, cost analysis and seeking the landowner's consent to allow reclamation to proceed.

- ***West Virginia AML*** – The dataset containing the West Virginia AML polygons was taken from the West Virginia GIS Technical Center Web site (<http://wvgis.wvu.edu/data/dataset.php?action=search&ID=150>) and was downloaded on July 10, 2008. Coal AML features were digitized from Abandoned Mine Land Reclamation source materials by the West Virginia University (WVU) Department of Geology & Geography and the WVU Natural Resource Analysis Center. This polygon dataset was published in 1996. A description of the dataset indicates that typical AML features include highwalls, portals, refuse piles and mining structures such as tipples. Acreage values should be considered as approximate estimations for the features and may not represent actual site conditions. The dataset does not include ownership or parcel information. For additional information on West Virginia's AML Program or the dataset, contact the West Virginia Office of Abandoned Mine Lands & Reclamation at <http://www.wvdep.org/item.cfm?ssid=12>.

- **Pennsylvania AML** – The dataset containing the Pennsylvania AML polygons was taken from the Pennsylvania Spatial Data Access Clearinghouse Web site and was downloaded July 10, 2008 (http://www.pasda.psu.edu/uci/MetadataDisplay.aspx?entry=PASDA&file=AMLInventorySites2008_07.xml&dataset=460). This dataset portrays the approximate location of Abandoned Mine Land Problem Areas containing public health, safety and public welfare problems created by past coal mining. The data represent the AML Inventory Sites, which are the boundary of an entire problem area and may contain multiple actual mining features. The dataset does not include ownership or parcel information. Most sites are owned privately. When needed, ownership information must be researched through other means, typically county real estate records. For additional information on Pennsylvania’s AML Program or to contact the Bureau of Abandoned Mine Reclamation, visit www.depweb.state.pa.us, keyword: Abandoned Mines.
- **Virginia AML** – The dataset containing the Virginia AML polygons was obtained from the Virginia Department of Mines, Minerals and Energy’s Division of Mined Land Reclamation on January 21, 2008. The dataset represents polygons of mines extracted from U.S. Geological Survey (USGS) topographic maps, last photo revised in the late 1970s and early 1980s. Some of these areas may represent sites that have been re-mined. For more information, contact the Virginia Department of Mines, Minerals and Energy’s Title IV AML program at dmlrinfo@dmme.virginia.gov or visit <http://www.mme.state.va.us/>.
- **Virginia Orphaned Mineral Mines** – The dataset containing the Virginia Orphaned Mineral Mine point data was obtained from the Virginia Department of Mines, Minerals and Energy’s Division of Mineral Mining and was downloaded August 29, 2008. This dataset represents orphaned mineral mining sites in Virginia operated prior to 1968. For additional information on Virginia’s Orphaned Mineral Mines program or contacting the Virginia Department of Mines, Minerals and Energy, visit <http://www.mme.state.va.us/DMM/orphaned%20land.shtml>.

In addition, the following GIS data were compiled and used to produce the EPA renewable energy potential maps.

National Renewable Energy Laboratory (NREL) Data

NREL data were downloaded on October 12, 2007 (<http://www.nrel.gov/gis/>). Specific information on how the data were collected by NREL is available at: http://www.nrel.gov/gis/data_analysis.html.

- High resolution direct normal solar resource data for the lower 48 states and low resolution direct normal solar data for AK, HI and PR: Used to determine potential for utility scale concentrating solar power (CSP) Stirling engine system, utility scale CSP trough and power tower systems, and utility scale PV solar power.
- High resolution latitude tilt collected solar resource data for the lower 48 states and low resolution latitude tilt data for AK, HI and PR: Used to determine potential for non-grid connected PV solar power.
- Low resolution wind data for the lower 48 states and high resolution wind data for AK, AR, AZ, CA, CO, CT, DC, DE, HI, ID, IL, IN, MA, MD, ME, MI, MO, NE, NC, ND, NH, NJ, NM, NV, MT, OH, OR, PA, PR, RI, SD, UT, VA, VT, WA, WV, and WY: Used to determine potential for utility scale wind, community wind and non-grid connected wind.
- Biomass data: Biomass resources available by county, used to determine potential for biorefinery and biopower facility siting.
- FEMA Transmission Lines (FEMA Electric): Used to determine the distance to transmission lines. Note: there is more accurate transmission line data available from other sources, but due to security concerns they are not publicly available and therefore not used in this analysis.
- Puerto Rico Transmission Line Data: Used to determine the distance to transmission lines. This information was digitized by NREL from paper maps obtained from an unreferenced source in 2000.

NREL resource potential information is described below.

Solar Resource		Wind Resource			Biomass Resource	
	Resource Potential	Power Class	Resource Potential	50 m Wind Power Density (Watts/m ² ; W/m ²)	Metric Tons/ Year	Resource Potential
< 4	Moderate	1	Poor	0 - 200	< 50,000	Low
> 4 - 5	Good	2	Marginal	200 - 300	50,000 - 100,000	Marginal
> 5 - 6	Very Good	3	Fair	300 - 400	100,000 - 150,000	Good
> 6	Excellent	4	Good	400 - 500	150,000 - 250,000	Very Good
		5	Excellent	500 - 600	250,000 - 500,000	Excellent
		6	Outstanding	600 - 800	> 500,000	Outstanding
		7	Superb	> 800		

Southern Methodist University (SMU) Data

Geothermal data were obtained from SMU.

- Temperature at depths information was obtained from SMU on June 27, 2009 in grid format. Depths provided were from 3 to 10 kilometers (km) in ½ km increments. (Dr. David Blackwell, Maria Richards and Petru Negraru, 2006, SMU Geothermal Laboratory Temperature Maps)
- Surface temperature grid depth information was obtained from SMU on June 27, 2009. (Dr. David Blackwell, Maria Richards and Petru Negraru, 2006, SMU Geothermal Laboratory Temperature Maps)
- Heat flow gradient data were obtained from the 2004 Geothermal Map of the United States on May 1, 2009. (Dr. David Blackwell and Maria Richards, Geothermal Map of North America, AAPG Map, scale 1:6,500,000, Product Code 423, 2004)

Renewable Energy Zone (REZ) Data

Renewable Energy Zones (REZ) typically look at high renewable resource areas (i.e., areas that have a high potential for generating a specific number of megawatts via solar, wind, biomass, or geothermal). From these high resource areas, exclusion and avoidance areas, such as sensitive environmental areas and inaccessible areas, among others, are removed and the remaining area is identified as a prime area for renewable energy development. Four REZ areas were identified when this study was completed; however other states and regions are in the process of creating and generating REZs.

REZ data were obtained from the following sources

- Western Governors Association (WGA) and Department of Energy jointly produced the Western REZ. This dataset was provided by the Western Governors Association on July 14, 2009.
- Bureau of Land Management (BLM) provided the BLM Solar Zones; these files were downloaded from <http://solareis.anl.gov/eis/maps/index.cfm> on July 14, 2009.
- Colorado State Wind and Solar Generation Development Areas (CO GDA) were obtained from the Governor’s Energy Office on July 14, 2009.
- California Competitive Renewable Energy Zones (CA REZ) were downloaded on July 19, 2009 from <http://www.energy.ca.gov/reti/documents/index.html>.

Database of State Incentives for Renewables & Efficiency (DSIRE) Data

DOE’s DSIRE Web site is a comprehensive database of information on state, local, utility, and federal incentives and policies that promote renewable energy and energy efficiency. DSIRE was consulted for information for the PV policy driven maps. Analysis was completed October 23, 2009. Please refer to <http://www.dsireusa.org/> for the most up-to-date information regarding state and federal policies.

ESRI Data

ESRI software, copyright 2001-2006

- U.S. Highways (highways.sdc): Used to calculate the approximate distance to the nearest graded road.
- U.S. States (states.sdc): Used to provide state outlines for mapping purposes.
- U.S. National Transportation Atlas Railroads (rail100k): Used to calculate the approximate distance to the nearest railway.

COMMON ATTRIBUTES

The following is a description of attributes used in the data tables that accompanies the EPA renewable energy potential maps, which is available at:

http://www.epa.gov/renewableenergyland/maps/ocpa_renewable_energy_data.xls.

Attribute Name	Attribute Description
EPA Reg	EPA region where the site is located
Program	Program from which data were obtained
EPA ID/ BF Acres Property ID	EPA or state unique identification code
Site ID/ BF Grant IDs	EPA site ID, brownfield grant ID or state ID
Site Name	Name of the property
Landfill Owner	Organization that owns the landfill
Landfill Owner Type	Denotes if landfill owner is a public or private organization
City	City where the site is located
State	State where the site is located (Some of the sites in the Virginia Coal AML dataset map in neighboring states, but were included for the purposes of this study due to their close proximity to Virginia. These sites are listed within the state they mapped in, but are marked with an asterisk.)
Federal Facility	Indicates whether the site is a federal facility
Mapped Acreage	Acreage used for mapping
State Renewable Portfolio Standard (RPS)	Indicates which states have an RPS, RPS goal, solar set-aside, solar multiplier, or distributed generation provision.
Renewable Energy Zones (REZ)	Renewable Energy Zones as established by the Western Governors Association and the Department of Energy, BLM and States of Colorado and California. These zones take into consideration both resource potential and exclusion zones.
Renewable Energy Potential Types	Indicates which renewable energy types have potential at the site
*Utility Wind Map	Indicates sites with utility scale wind energy generation potential
*Comm Wind Map	Indicates sites with community wind energy generation potential
*Non-Grid Wind Map	Indicates sites with non-grid connected wind energy generation potential
*CSP Stirling Engine Solar Map	Indicates sites with utility scale stirling engine concentrating solar power (CSP) energy generation potential
*CSP Trough and Power Tower Solar Map	Indicates sites with utility scale trough and power tower CSP energy generation potential
*PV Utility Solar Map	Indicates sites with utility scale photovoltaic (PV) solar energy generation potential
* PV Policy Driven Solar Map	Indicates sites in states that have renewable portfolio standards (or goals) with one or more of the following provisions: solar set-aside; solar multiplier; or distributed generation. While the sites meet PV utility scale requirements for size and distance to transmission and roads, there is no screening criteria for solar resource availability.
*Non-Grid PV Solar Map	Indicates sites with non-grid connected PV generation potential
*Biopower Facility Map	Indicates sites with biopower facility siting potential
*Biorefinery Facility Map	Indicates sites with biorefinery facility siting potential

Attribute Name	Attribute Description
*Candidate for Landfill Gas Energy Project	A landfill that is accepting waste or has been closed for five years or less, has at least one million tons of waste and does not have an operational or under construction LFGE project; or is designated based on actual interest or planning
*Potential for Landfill Gas Energy Project	A landfill that does not meet the candidate definition due to complete or incomplete data. However, the landfill could have LFGE project potential based on site-specific needs or if data were complete.
*Operational Landfill Gas Energy Project	The landfill gas energy project is commercially operational
*Construction Landfill Gas Energy Project	The landfill gas energy project is under construction
*Shutdown Landfill Gas Energy Project	The landfill gas energy project has ceased operation
*Geothermal Flash Power Plant	Indicates sites with geothermal flash power plant potential
*Geothermal Binary Power Plant Map	Indicates sites with geothermal binary power plant potential
*Geothermal Heat Pump Map	Indicates sites with geothermal heat pump potential
Latitude	Latitude in decimal degrees, NAD 27 projection
Longitude	Longitude in decimal degrees, NAD 27 projection
Dist Power (miles)	Distance to the nearest transmission line
KV	Kilovolt capacity of the nearest transmission line
Dist Hwys (miles)	Distance to the nearest graded road
Dist Rail (miles)	Distance to the nearest railway
Max Wind	Measurement of the wind power class, measured at 50 meters above ground
Wind Range (W/m ² at 50m)	Measurement of the wind speed, measured in Watts per meter squared (W/m ²) at 50 meters
Wind Potential	Description of the wind energy potential
Max DNI Solar (kWh/m ² /day)	Measurement of the direct normal irradiance (DNI) solar resource availability in kilowatt hour per meter squared per day (kWh/m ² /day) for utility scale projects
DNI Solar Potential	Description of the solar energy potential for utility scale project
Max LATilt Solar (kWh/m ² /day)	Measurement of the solar resource availability in kilowatt hour per meter squared per day (kWh/m ² /day) for non-grid connected projects
Non-Grid PV Solar Potential	Description of the solar energy potential for non-grid connected projects
Cum Biomass Resources (metric tons/yr w/i 50 miles)	Cumulative biomass resources in metric tons/year, used to determine biopower facility siting potential (includes: crops, forests, primary and secondary mills; urban wood waste; and methane emissions from manure management, landfills, and domestic wastewater treatment)
Biopower Potential	Description of the biomass energy potential for siting biopower facilities
Cum Crop Residues (metric tons/yr w/i 50 miles)	Cumulative crop residues in metric tons/year, used to determine biorefinery siting potential (includes: crops; forests; primary and secondary mills and urban wood waste)
Biorefinery Potential	Description of the biomass energy potential for siting biorefinery facilities
Crops (metric tons/yr w/i 50 miles)	Crop residues (dry metric tons/year), includes residues from corn, wheat, soybeans, cotton, sorghum, barley, oats, rice, rye, canola, dry edible beans, dry edible peas, peanuts, potatoes, safflower, sunflower, sugarcane and flaxseed
Manure (metric tons/yr w/i 50 miles)	Methane emissions from manure management (metric tons/year), includes dairy cows, beef cows, hogs and pigs, sheep, chickens and layers, broilers and turkey
Forest (metric tons/yr w/i 50 miles)	Forest residues (dry metric tons/year), includes logging residues and other removable material left after carrying out silviculture operations and site conversions
Primmill (metric tons/yr w/i 50 miles)	Primary mill residues (dry metric tons/year), includes wood materials (coarse and fine) and bark generated at manufacturing plants (primary wood-using mills) when round wood products are processed into primary wood products
Secmil (metric tons/yr w/i 50 miles)	Secondary mill residues (dry metric tons/year), includes wood scraps and sawdust from woodworking shops
Urban (metric tons/yr w/i 50 miles)	Urban wood residues (dry metric tons/year), includes wood residues from wood chips, pallets, utility tree trimming and/or private tree companies, and construction and demolition sites

Attribute Name	Attribute Description
Landfill (metric tons/yr w/i 50 miles)	Methane emissions from landfills (metric tons/year)
WWTreat (metric tons/yr w/i 50 miles)	Methane emissions from domestic wastewater treatment (metric tons/year)
Energy Crops (metric tons/yr w/i 50 miles)	Energy crops (dry metric tons/year), includes hybrid poplar, willow and switchgrass on Conservation Reserve Program lands
**Cum Biomass Resources (TJ/yr w/i 50 miles)	Cumulative biomass resources (terajoule/year) (includes: crops, forests, primary and secondary mills; urban wood waste; and methane emissions from manure management, landfills and domestic wastewater treatment)
**Cum Crop Residues (TJ/yr w/i 50 miles)	Cumulative crop residues (terajoule/year) (includes: crops; forests; primary and secondary mills and urban wood waste)
**Crops (TJ/yr w/i 50 miles)	Crop residues (terajoule/year) a conversion factor of 6,500 BTU/pound was used
**Manure (TJ /yr w/i 50 miles)	Methane emissions from manure management (terajoule/year), a conversion factor of 24,000 BTU/pound was used
**Forest (TJ/yr w/i 50 miles)	Forest residues (terajoule/year), a conversion factor of 8,500 BTU/pound was used
**Primmill (TJ/yr w/i 50 miles)	Primary mill residues (terajoule/year), a conversion factor of 4,700 BTU/pound was used
**Secmil (TJ/yr w/i 50 miles)	Secondary mill residues (terajoule/year), a conversion factor of 4,700 BTU/pound was used
**Urban (TJ/yr w/i 50 miles)	Urban wood residues (terajoule/year), a conversion factor of 4,700 BTU/pound was used
**Landfill (TJ/yr w/i 50 miles)	Methane emissions from landfills (terajoule/year), a conversion factor of 24,000 BTU/pound was used
**WWTreat (TJ/yr w/i 50 miles)	Methane emissions from domestic wastewater treatment (terajoule/year) , a conversion factor of 24,000 BTU/pound was used
**Energy Crops (TJ/yr w/i 50 miles)	Energy crops (terajoule/yr), includes hybrid poplar, willow and switchgrass on Conservation Reserve Program lands a conversion factor of 6,500 BTU/pound was used
Landfill Status	Open/closed status of landfill
Landfill Year Opened	Year landfill opened or began accepting waste
Landfill Year Closed	Year landfill closed, is expected to close, stopped accepting waste or is expected to stop accepting waste
Landfill Designed Area (acres)	Design waste mass area of landfill in acres
Landfill Current Area (acres)	Current waste mass area of landfill in acres
Landfill Total Area (acres)	Total area of land the landfill is located on
Landfill Designed Capacity (tons)	Waste design capacity of landfill in tons
Landfill Waste in Place (tons)	Waste-in-place at the landfill in tons
Landfill Waste in Place Year	Year corresponding to the waste-in-place at the landfill
Surface_Temp (C°)	Mean ground surface temperature in degrees Celsius
3km (C°)	Temperature in degrees Celsius at 3 km
3_5km (C°)	Temperature in degrees Celsius at 3.5 km
4km (C°)	Temperature in degrees Celsius at 4 km
4_5km (C°)	Temperature in degrees Celsius at 4.5 km
5km (C°)	Temperature in degrees Celsius at 5 km
5_5km (C°)	Temperature in degrees Celsius at 5.5 km
6km (C°)	Temperature in degrees Celsius at 6 km
6_5km (C°)	Temperature in degrees Celsius at 6.5 km
7km (C°)	Temperature in degrees Celsius at 7 km
7_5km (C°)	Temperature in degrees Celsius at 7.5 km
8km (C°)	Temperature in degrees Celsius at 8 km
8_5km (C°)	Temperature in degrees Celsius at 8.5 km
9km (C°)	Temperature in degrees Celsius at 9 km

Attribute Name	Attribute Description
9_5km (C°)	Temperature in degrees Celsius at 9.5 km
10km (C°)	Temperature in degrees Celsius at 10 km
Heat Flow (mW/m2)	Heat flow in megawatts per meter squared

* These attributes have comments which indicate the screening criteria for each map

** One terajoule is equivalent to 947,817,077.75 BTUs

CONTACT INFORMATION

For more information, visit <http://www.epa.gov/renewableenergyland> or contact EPA's OSWER Center for Program Analysis (CPA) at cleanenergy@epa.gov.

LIST OF MAPS OF EPA AND STATE TRACKED SITES WITH RENEWABLE ENERGY GENERATION POTENTIAL

This spreadsheet lists the types of renewable energy potential on contaminated land and mining sites applicable to each state, based on the screening criteria (see Mapping Methodology section). Please note that Alaska and Hawaii may have additional potential; the only maps that could be developed, due to limited data resources, are non-grid connected wind, community wind, non-grid connected PV solar, and landfill gas energy. Similarly, the only maps that could be developed for Puerto Rico were wind, solar and landfill gas energy.

State	Utility Scale Wind	Community Wind	Non-Grid Wind	Utility Scale CSP Solar	Utility Scale Photovoltaic (PV) Solar	PV Solar Policy Driven	Non-Grid PV Solar	Biopower Facility	Biorefinery Facility	Landfill Gas Energy	Geothermal Flash Power Plant	Geothermal Binary Power Plant	Geothermal Heat Pump
Alabama							X	X	X	X		X	X
Alaska			X				X			X			
Arizona			X	X	X	X	X	X	X	X	X	X	X
Arkansas							X	X	X	X	X	X	X
California	X	X	X	X	X		X	X	X	X	X	X	X
Colorado	X	X	X	X	X	X	X	X	X	X	X	X	X
Connecticut		X	X				X	X	X	X			X
Delaware						X	X	X	X	X			X
District of Columbia						X	X	X	X				X
Florida							X	X	X	X		X	X
Georgia			X				X	X	X	X			X
Hawaii			X				X			X			
Idaho	X	X	X		X		X	X	X	X	X	X	X
Illinois		X	X			X	X	X	X	X			X
Indiana		X	X				X	X	X	X			X
Iowa		X	X				X	X	X	X			X
Kansas		X	X		X		X	X	X	X		X	X
Kentucky							X	X	X	X			X
Louisiana							X	X	X	X	X	X	X
Maine			X				X	X	X	X			X
Maryland						X	X	X	X	X			X
Massachusetts		X	X				X	X	X	X			X
Michigan		X	X			X	X	X	X	X			X
Minnesota	X	X	X				X	X	X	X			X
Mississippi							X	X	X	X		X	X
Missouri			X			X	X	X	X	X			X
Montana	X	X	X		X		X	X	X	X	X	X	X
Nebraska	X	X	X		X		X	X	X	X			X
Nevada		X	X	X	X	X	X	X	X	X	X	X	X
New Hampshire						X	X	X	X	X			X

LIST OF MAPS OF EPA AND STATE TRACKED SITES WITH RENEWABLE ENERGY GENERATION POTENTIAL (CONTINUED)

State	Utility Scale Wind	Community Wind	Non-Grid Wind	Utility Scale CSP Solar	Utility Scale Photovoltaic (PV) Solar	Utility PV Solar (Policy Driven)	Non-Grid PV Solar	Biopower Facility	Biorefinery Facility	Landfill Gas Energy	Geothermal Flash Power Plant	Geothermal Binary Power Plant	Geothermal Heat Pump
New Jersey						X	X	X	X	X			X
New Mexico	X	X	X	X	X	X	X	X	X	X	X	X	X
New York		X	X			X	X	X	X	X			X
North Carolina		X	X			X	X	X	X	X			X
North Dakota	X	X	X				X	X	X	X		X	
Ohio		X	X			X	X	X	X	X			X
Oklahoma	X	X	X		X		X	X	X	X		X	X
Oregon		X	X		X	X	X	X	X	X	X	X	X
Pennsylvania		X	X			X	X	X	X	X		X	X
Puerto Rico	X		X		X		X			X			
Rhode Island		X	X				X	X	X	X			X
South Carolina		X	X				X	X	X	X			X
South Dakota		X	X		X		X	X	X	X			X
Tennessee		X	X				X	X	X	X			X
Texas	X	X	X	X	X	X	X	X	X	X	X	X	X
Utah	X	X	X	X	X	X	X	X		X	X	X	X
Vermont			X				X	X	X	X			X
Virginia		X					X	X	X	X			X
Washington	X	X	X		X	X	X	X	X	X	X	X	X
West Virginia							X	X	X	X			X
Wisconsin		X	X				X	X	X	X			X
Wyoming	X	X	X		X		X	X	X	X		X	X