Data Documentation for Mapping and Screening Criteria for Renewable Energy Generation Potential on EPA and State Tracked Sites

RE-Powering America's Land Initiative
Revised September 2017

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Overview

The U.S. Environmental Protection Agency (EPA) Office of Land and Emergency Management (OLEM), Office of Partnerships, Communication and Analysis (OCPA) created the RE-Powering America's Land Initiative to demonstrate the enormous potential that contaminated lands, landfills, and mine sites provide for developing renewable energy in the United States. To that end, the Initiative developed the RE-Powering Mapper tool. The tool is a publicly available spatial database of over 81,000 sites that have been pre-screened for renewable energy potential. This document details the screening process and data underlying the Mapper.[1]

EPA developed national level site screening criteria in partnership with the U.S. Department of Energy (DOE) National Renewable Energy Laboratory (NREL). The most recent screening occurred in August of 2015. The screening criteria, described in this document, demonstrate the potential to reuse contaminated land for solar, wind, biomass, and geothermal energy production based on resource availability, acreage, and distance to transmission lines and graded roads. Although these sites were preliminarily screened for renewable energy potential based on a number of technical considerations, many other factors should be considered in order to determine a project's ultimate feasibility. Renewable energy developers and/or relevant stakeholders usually conduct rigorous site-specific analyses to verify both technical and economic feasibility. Many sites may be ready for reuse, while other sites may have long-term institutional/engineering controls in place or are still undergoing assessment and/or clean-up. The Mapper renewable energy layers include a "Site Status" attribute field which directs users to the best site-specific environmental information.

The federal- and state-tracked sites included in this screening represent a subset of nationwide contaminated lands, landfills, and mine sites. RE-Powering screened sites are currently tracked through EPA remediation and grant programs, as well as sites tracked by 11 state agencies. Additional sites are tracked at the state and local level, but have not been screened as part of this effort.

[1] In September 2017, the RE-Powering Initiative converted its Mapper Tool to an online interactive web application. As a part of this conversion, however, neither the screening criteria nor the underlying data have changed.

Data, Criteria and Methodology

EPA developed an inventory of contaminated lands, landfills, and mine sites from various sources, including state agencies. From this inventory, EPA validated coordinates provided for sites and excluded sites where the coordinates did not match the state information provided. This subset of EPA and state tracked sites was then screened for renewable energy resource potential, as described in the Screening Criteria below.

Site Information Datasets

EPA and state databases are refreshed regularly with information such as new sites and updated acreage. The information in the RE-Powering Mapper dataset provides a snapshot in time, as described in the Datasets sections. The use of site-specific information provided herein should only be used with the understanding that the information may change over time.

EPA does not maintain or manage the state datasets. Currently, snapshots of the following states datasets are included: California, Hawai'i, Illinois, Massachusetts, New Jersey, New York, Oregon, Pennsylvania, Texas, Virginia, and West Virginia.

The following data sources were used to develop the inventory of EPA and state tracked sites evaluated as part of this analysis. Site information and screening data were needed to conduct this analysis.

EPA Datasets

Note: EPA datasets are updated continuously so these data provide a snapshot in time.

Program Name	Description of Dataset used in Analyses	Data Current	Date of Screening
AML Program (Abandoned Mine Lands)	Includes all abandoned hardrock mines and mineral processing sites listed in the Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS). Including abandoned mine sites on the National Priorities List (NPL), often referred to as "Superfund" Sites and abandoned mine sites where EPA also has made emergency response actions.	11/2013	6/2015
Brownfields	Brownfields are real property where expansion, redevelopment, or reuse may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant. Brownfields are often found in and around economically depressed neighborhoods. Includes data in the Assessment Cleanup and Redevelopment Exchange System (ACRES) database. Data include 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.	3/2015	6/2015
Resource Conservation and Recovery Act (RCRA)	RCRA sites are commercial, industrial, and federal facilities that treat, store, or dispose of hazardous wastes that require cleanup of the contamination under the RCRA Corrective Action (CA) Program. Includes all sites from the RCRA 2020 Universe Inventory.	10/2014	6/2015
Superfund	These sites are contaminated and include industrial facilities, waste management sites, mining and sediment sites, and federal facilities Site data for these sites were extracted from CERCLIS.[2] This universe includes sites listed on, proposed to, and deleted from the National Priorities List (NPL), as well as some sites that are not included on the NPL (e.g.., removal sites and others), in addition to Superfund Alternative Approach sites.	11/2013	6/2015
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. This universe of sites includes all landfills that have partnered with LMOP. Visit EPA's LMOP website at www.epa.gov/lmop/ for more information and definitions of landfill gas energy projects.	3/2015	6/2015

[2] The data for these sites were gathered during the time of transition from CERCLIS to SEMS; thus, sites that were not in CERCLIS were pulled from Federal Register information from 11/2013 to 6/2015 when possible.

State Agencies

Note: State datasets are updated continuously so this provides a snapshot in time. Please check with the appropriate state agencies for the most up-to-date information.

State	Contact Information
California	California Department of Toxic Substances Control (CA DTSC) EnviroStor 1001 I Street P.O. Box 806 Sacramento, CA 95812-0806 1-877-786-9427 Email: envirostor@dtsc.ca.gov http://www.envirostor.dtsc.ca.gov/public/
Hawai'i	Hawai'i State Department of Health (HI DOH) Hazard Evaluation and Emergency Response Office 919 Ala Moana Boulevard, Room 206 Honolulu, HI 96814 Telephone: (808) 586-4249 Fax: (808) 586-7537 http://eha-web.doh.hawaii.gov/eha-cma/Org/HEER
Illinois	Remediation Projects Management Section 1021 North Grand Avenue East P.O. Box 19276 Springfield, Illinois 62794-9276 217-524-3300 Site Remediation program: http://www.epa.illinois.gov/topics/cleanup-programs/srp/index Brownfield program: http://www.epa.illinois.gov/topics/cleanup-programs/brownfields/index
New Jersey	Sustainability and Green Energy (SAGE) New Jersey Department of Environmental Protection 7th Floor, East Wing P.O. Box 402, Mail Code: 401-07E 401 East State Street Trenton, NJ 08625 609-292-8601 Email: sage_inquiries@dep.state.nj.us www.nj.gov/dep/sage/
New York	New York Department of Environmental Conservation (NYS DEC) Environmental Remediation 625 Broadway Albany, NY 12233-7012 518-402-9764 Email: derweb@gw.dec.state.ny.us www.dec.ny.gov/chemical/brownfields.html
Massachusetts	Clean Energy Results Program 100 Cambridge Street, Suite 1020 Boston, MA 02114 (617) 626-1000 Email: BWSC.Information@state.ma.us http://www.mass.gov/eea/agencies/massdep/climate-energy/energy/

State	Contact Information
Oregon	Oregon Department of Environmental Quality (OR DEQ) Environmental Cleanup 811 SW Sixth Ave. Portland, OR 97204-1390 503-229-5512 Email: WISTAR.Gil@deq.state.or.us or DEQInfo@deq.state.or.us
Pennsylvania	Bureau of Abandoned Mine Reclamation (PA BAMR) Rachel Carson State Office Building P.O. Box 8461 Harrisburg, PA 17105-8461 717-783-2267 Email: RA-epcontactus@pa.gov www.portal.state.pa.us/portal/server.pt/community/abandoned_mine_reclamation/13961
Texas	Superfund Section, Remediation Division, Texas Commission on Environmental Quality Texas Commission on Environmental Quality, MC-136 P.O. Box 13087 MC136 Austin, Texas 78711- 3087 (512) 239-2479 Fax: (512) 239-2450 Email: carol.rahmani@tceq.texas.gov
Virginia	Coal AML Virginia Division of Mined Land Reclamation (VA DMLR) 3405 Mountain Empire Road P.O. Drawer 900 Big Stone Gap, VA 24219 276-523-8100 Email: dmlrinfo@dmme.virginia.gov https://www.dmme.virginia.gov/DMLR/DmlrLandingPage.shtml Orphaned Mineral Mines Virginia Division of Mineral Mining (VA DMM) Suite 400 Charlottesville, VA 22903-0667 434951-6310 Email: dmmInfo@dmme.virginia.gov https://www.dmme.virginia.gov/DMM/divisionmineralmining.shtml
West Virginia	Office of Abandoned Mine Lands and Reclamation (WV AMLR) 601 57th Street, SE Charleston, WV 25304 304-926-0499 Contact form: http://www.dep.wv.gov/Pages/contact.aspx www.dep.wv.gov/aml/Pages/default.aspx

State Tracked Abandoned Mine Lands Datasets

Two types of AMLs were included in this study. Some of 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 other type of AML includes hard rock and other mineral mine sites.

State	Description of Dataset used in Analyses	Data Current	Date of Screening
West Virginia AML	This dataset is a polygon shapefile and was downloaded from the West Virginia Geographic Information System (GIS) Technical Center website (http://wvgis.wvu.edu/data/dataset.php?action=search&ID=150). 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 high walls, 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.	7/10/2008	6/2015
Pennsylvania AML	This dataset is a polygon shapefile and was downloaded from the Pennsylvania Spatial Data Access Clearinghouse website (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.	7/05/2012	6/2015
Virginia AML	This dataset is a polygon shapefile and was obtained from the Virginia Department of Mines, Minerals and Energy's Division of Mined Land Reclamation. 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.	1/21/2008	6/2015
Virginia Orphaned Mineral Mines	The dataset was obtained from the Virginia Department of Mines, Minerals and Energy's Division of Mineral Mining. This dataset represents orphaned mineral mining sites in Virginia operated 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.	7/16/2012	6/2015
New Jersey AML	This dataset is a polygon shapefile and contains abandoned mine lands in New Jersey.	11/6/2011	6/2015
New Jersey Sand and Gravel Operations	This dataset is a polygon shapefile and contains registered and non-registered sand and gravel operations in New Jersey. Only non-registered sand and gravel operations were evaluated in this study.	11/16/2011	6/2015

State Tracked Contaminated Site Datasets

Most states track and remediate contaminated sites. Information tracked, reported, and provided varies from state to state. The data gathered as part of this study was "standardized" in a manner to capture the most important information consistently reported across a wide range of states. Locations were verified to map in the associated states.

Name	Description of Dataset used in Analyses	Data Current	Date of Screening
California Department of Toxic Substances Control (DTSC)	DTSC populates the EnviroStor database system with information about sites that are known to be contaminated with hazardous substances as well as information on uncharacterized properties where further studies may reveal problems. The dataset was downloaded from http://www.envirostor.dtsc.ca.gov/public/data_download.asp	9/8/2011	6/2015
Hawai'i State Department of Health	The Hawai'i State Department of Health - Hazard Evaluation and Emergency Response (HEER) Office provided an inventory of brownfield sites, http://eha-web.doh.hawaii.gov/eha-cma/Leaders/HEER/public-records. Note that summary information is available in two forms: a HEER Sites of Interest Lookup Spreadsheet, and a Public Record Report in single page per site PDF format.	3/2013	6/2015
Illinois Site Remediation Program	Identifies the status of all voluntary remediation projects administered through the Pre-Notice Site Cleanup Program (1989 to 1995) and the Site Remediation Program (1996 to the present).	4/2015	6/2015
Illinois State Response Action Program	This dataset identifies all sites that have been identified as having potential contamination not covered by another program, some have been addressed under the Illinois EPA's State Sites Unit.	4/2015	6/2015
New Jersey - Known Contaminated Sites	The Known Contaminated Sites List (KCSNJ) for New Jersey (Non-Homeowner) are those non-homeowner sites and properties within the state where contamination of soil or ground water has been confirmed at levels equal to or greater than applicable standards. This list of Known Contaminated Sites may include sites where remediation is either currently under way, required but not yet initiated, or has been completed. The dataset was provided by New Jersey.	11/16/2011	6/2015
New Jersey – Landfills	This dataset is a polygon shapefile of a parcel or parcels greater than 35 acres located in New Jersey. New Jersey provided this dataset.	11/21/2011	6/2015
New York – Environmental Remediation Sites	This dataset is a polygon shapefile and contains records of the sites which have been remediated or are being managed under one of Division of Environmental Remediation's (DER) remedial programs (i.e., State Superfund, Brownfield Cleanup, etc.). All sites listed on the "Registry of Inactive Hazardous Waste Disposal Sites in New York State" are included in this database. The Database also includes sites with entries on the "Registry of Institutional and Engineering Controls in New York State." This dataset was provided by New York.	7/8/2011	6/2015
Massachusetts Land Disposal of Solid Waste	The Solid Waste Land Disposal data layer was compiled by the Department of Environmental Protection (MassDEP) to track the locations of land disposal of solid waste. Land Disposal refers to an operation established in accordance with a valid site assignment for the disposal of solid waste into or on land (Landfill), or a location for disposal of solid waste from one or more sources which is not established or maintained pursuant to a valid site assignment or permit (Dumping Ground).	4/2014	6/2015
Massachusetts Contaminated Land Profiles	This spreadsheet describes sites that have had a release of oil or hazardous materials and are regulated under Massachusetts regulations.	4/2014	6/2015
Oregon – Environmental Cleanup Sites	The Oregon Department of Environmental Quality (DEQ) maintains its Environmental Cleanup Site Information (ECSI) database to track sites in the state with known or potential contamination from hazardous substances, and to document sites where DEQ has determined that no further action is required. Data in ECSI is "working information" used by DEQ's Environmental Cleanup Section. This dataset was provided by Oregon.	9/12/2011	6/2015
Texas Municipal Solid Waste Facilities	A spreadsheet listing issued permits and other authorizations as well as pending applications for MSW landfills and processing facilities that are active, inactive, or not yet constructed. As well as issued and revoked permits and other authorizations for MSW landfills and processing facilities that have closed, and applications that were withdrawn or denied.	4/2015	6/2015

Name	Description of Dataset used in Analyses	Data Current	Date of Screening
Texas Superfund Sites	Sites in the State of Texas that have been designated as Superfund cleanup sites; it includes both Federal and State sites. Note Federal sites were excluded for the purpose of this analysis as to not double count those already included in the EPA Superfund dataset.	7/2014	6/2015
Texas Voluntary Cleanup Sites (VCP)	The Texas VCP provides administrative, technical, and legal incentives to encourage the cleanup of contaminated sites in Texas. All non-responsible parties, including future lenders and landowners, receive protection from liability to the state of Texas for cleanup of sites under the VCP, most of the constraints for completing real estate transactions at those sites are eliminated. As a result, many unused or under used properties may be restored to economically productive or community beneficial use.	1/2015	6/2015

Screening Criteria

The following screening criteria used to evaluate renewable energy potential were developed by EPA and NREL. Although there are other critical factors for siting renewable energy facilities (e.g., slope), they were not considered in this analysis.

	Estimated RE Project Capacity Range	Renewable Energy Resource Availability	Acreage (acres)	Distance to Transmission (miles)	Distance to Graded Roads (miles)
Solar PV		**Direct Normal** (kWh/m2/day)			
Utility scale	> 6.5 MW	≥ 5.0	≥ 40	≤ 10	≤ 10
Large scale	> 300 kW	≥ 3.5	≥ 2	≤ 1	≤ 1
Off-grid	N/A	≥ 2.5	--	--	--
CSP		**Direct Normal** (kWh/m2/day)			
Stirling Engine	> 5 MW	≥ 6.0	≥ 40	≤ 10	≤ 10
Trough & Power tower	> 30 MW	≥ 6.0	≥ 250	≤ 10	≤ 10
Wind		**Wind speed (m/s)**			
Utility scale	> 10 MW	5.5 m/s at 80 m	≥ 100	≤ 10	≤ 10
Large scale	> 5 MW	5.5 m/s at 80 m	≥ 40	≤ 10	≤ 10
1-2 Turbine sites	> 1 MW turbine	5.5 m/s at 80 m	≥ 2	≤ 1	≤ 1
Off-grid	N/A	5.5 m/s at 50 m	≥ 0.25	--	-
Biomass		**Biomass potential within 50 miles** (metric tons/yr)			
Biopower	> 10 MW	≥ 280,000	≥ 50	≤ 10	≤ 3 road; ≤ 8 rail
Biorefinery	> 10,000 gal/yr	≥ 700,000	≥ 50	N/A	≤ 3 road; ≤ 8 rail
Geothermal					
		Distance to "Identified Hydrothermal Sites" (miles) *OR* **Favorability Rating**			
Hydrothermal	N/A	Distance: ≤ 10 Favorability: ≥ 4	≥ 10	≤ 10	≤ 10
		Temperature at 4.5 km Well Depth			
Enhanced Geothermal Systems	N/A	≥ 150 C (300 F)	≥ 10	≤ 10	≤ 10
		Near Surface Temperature		**Other Considerations**	
Heat Pump	**N/A**	**10 C (50 F) to 24 C (75 F)**		All sites which have buildings or other heating or cooling needs (i.e., office buildings, warehouses, green houses) are generally considered favorable for geothermal heat pumps. This variable is not included in the prescreening.	

State Policies

The economic viability of renewable energy projects is tied closely to the policy and regulatory context of the jurisdiction where the installation would be sited. In addition to the renewable energy technology screen, the Mapper includes a layer with relevant policy information attributable to each state. The following table describes the type of information that was captured from the Department of Energy's Database of State Incentives for Renewables and Efficiency (DSIRE). The data for this layer was last retrieved March 2017. For more information about this database and for the most recent information, please see: http://www.dsireusa.org/

The following information is captured from DSIRE and included in the Mapper as a State Policies layer:

Data	Units	Date Accessed	Description
RPS	Yes/No/ Goal	March 2017	States with a Renewable Portfolio Standard or goal
RE-Powering Incentive	Yes/No	March 2017	Describes states with specific incentives to encourage RE-powering type projects
Physical Net-metering	Yes/No	March 2017	Does the state have physical net-metering?
Virtual Net-Metering	Yes/No	March 2017	Does the state have virtual net-metering?
Renewable Energy Tax Incentive	Yes/No	March 2017	Reports whether *state* has renewable energy tax incentives
Shared Renewable Energy Program	Yes/No	March 2017	Does the State have policies to specifically encourage community solar or some other form of shared renewables?
In State Shared Renewable Energy Program	Yes/No	March 2017	
Community Choice Aggregation	Yes/No	March 2017	Does the state have authorizing legislation that specifically allows community choice aggregation? http://www.leanenergyus.org/cca-by-state/
Electricity Retail Choice	Yes/No	March 2017	Whether electricity retail choice is easily available (that is, states have adopted electric retail choice programs that allow end-use customers to buy electricity from competitive retail suppliers)
Green Tariff	Yes/No	March 2017	Does the state have a green tariff?
RE-Powering Sites		Based on October 2016 RE-Powering Tracking Matrix	The total number of completed renewable energy sites
Screened Sites		Based on August 2015 data	Total number of sites screened in Mapper

Screening Methodology

All sites were screened by comparing the site location with renewable energy resources previously mapped (and regularly updated) by NREL. The sites were mapped against this resource potential. Specific renewable energy, site size and proximity to infrastructure criteria are applied to give the Mapper user a high level indication of sites with likely renewable energy potential. These criteria are described in the table above.

As noted in the Overview section of this document, this analysis represents an initial screening, and sites should be investigated further for both technical and economic feasibility. For example, although slope is a critical factor for siting some types of renewable energy, it was not considered in the 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 (many 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.

Sites may or may not be assessed and/or cleaned-up and ready to use. The Mapper database includes a link from each site to more information about the site's environmental conditions.

Boundary data are not collected consistently for EPA sites; therefore, each EPA tracked site was mapped using a single latitude and longitude point obtained from EPA's Program Office databases. In order to approximate the site size/boundary and estimate the 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 renewable energy resource values that the buffer covered were recorded for solar and wind resources. This methodology has limitations in that sites are typically not circles and latitude and longitude are not always recorded at the geographic center of the site. However, given these limitations, this method will allow a more accurate snapshot of what energy potential may be available at the site better than the single data point.

Acreage values for each site might not be representative of available land at each particular site, nor the total contaminated area. For example, many federal facilities on the National Priorities List (NPL) are listed "fence to fence," which encompasses the entire facility, rather than only the contaminated portions of the facility. As such, the potentially or formerly contaminated areas may represent only a portion of the total acreage of these Superfund sites. In addition, acreage values do not take into account the physical characteristics at the site (e.g., buildings, topography, tree cover, etc.) and, thus, may not represent the true usable acreage of the site.

Data for state tracked sites in West Virginia, Pennsylvania, Virginia abandoned mine lands (AML), New York, New Jersey AML, New Jersey Landfills, New Jersey Quarries and Texas Landfills were provided as polygons in ESRI shapefile format. The polygon data provides site boundaries, and as such circular buffers were not modeled for these sites, the polygon site boundaries were used for the analysis.

Data for state tracked sites in Virginia (Orphaned Mineral Mines), California, New Jersey Contaminated Land Sites, Texas (State Superfund and Voluntary Cleanup Program), Illinois, Massachusetts, and Oregon were mapped using a single latitude and longitude point; therefore, data were evaluated using the same methodology as was used for the EPA tracked sites.

Sites without coordinates were geocoded using the address provided. Geocoded site locations were verified by matching the location mapped by geocoded coordinates to the city provided in the database, approximately 600 EPA and State tracked sites were geocoded.

EPA and state tracked sites that were identified as having potentially incorrect latitude and longitude data (i.e., mapped locations did not match city or county as recorded or coordinates could not be obtained by geocoding) are excluded from the analysis. Approximately 1000 sites were eliminated from the screening due to issues with the location data.

Acreage is not a screening criterion for off-grid solar 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 to supplement the electricity provided to the site from traditional sources. In most cases, these systems would need to be interconnected to the existing utility grid and may be subject to utility regulations or policies. In some cases, an off-grid system may power a given load, (e.g., a small-scale pump and treat system).

With the exception of Puerto Rico and the Virgin Islands, the U.S. territories were not evaluated or included in this analysis as renewable energy resource and transmission data were not readily available for these territories. Biomass and geothermal resource data were not readily available for Puerto Rico and the Virgin Islands. Therefore, these renewable energy potential types were not evaluated for these sites. Geothermal data is limited for Hawai'i. Only known hydrothermal information was available at the time of this analysis.

The mapped acreage for landfills is the highest acreage value among landfill designed area, landfill current area and landfill total area.

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.

In instances where distances to transmission lines, highways, or rails are zero, the transmission line, highway, or rail intersects the site buffer, meaning that the infrastructure is present within the generated site boundary.

Screening Datasets

The following GIS data were compiled and used to perform the screening.

National Renewable Energy Laboratory (NREL) Data

Specific information on how the data were collected by NREL is available at: www.nrel.gov/gis/.

Resource Name	Description of Dataset used in Analyses	Date of Access
Lower 48 Direct Normal Resource (us9809_dni)	Direct normal solar resource data for the lower 48 states and Hawai'i. Used to determine potential for utility scale CSP Stirling engine system, utility scale CSP trough, and power tower systems, and all scales of solar PV.	6/2015
Alaska Direct Normal Resource (akdirect)	Direct normal solar resource data for Alaska. Used to determine potential for utility scale CSP Stirling engine system, utility scale CSP trough, and power tower systems, and all scales of solar PV.	6/2015
Caribbean Direct Normal Resource (csr_carib_dir)	Direct normal solar resource data for the Caribbean (Puerto Rico and Virgin Islands). Used to determine potential for utility scale CSP Stirling engine system, utility scale CSP trough, and power tower systems, and all scales of solar PV.	6/2015
Solid Biomass	Contains information about the biomass resources generated by county in the United States. It includes the following feedstock categories: crop residues, forest residues, primary mill residues, secondary mill residues, and urban wood waste. Used to determine potential for biorefinery and biopower facility siting. Data available for all jurisdictions except for Puerto Rico and Virgin Islands.	6/2015
Wind	Wind speed resource data at heights of 50, 80, 110, and140 meters (m); developed by AWS Truepower LLC. Wind speeds at 80-m height used to determine potential for wind energy at utility- and large-scale, as well as 1-2 turbine sites. Wind speeds at 50-m height used to determine potential for wind energy at off-grid scale to allow for use of smaller turbines.	7/2015

Homeland Security Infrastructure Program (HSIP) Data

Distances to transmission lines, substations, and rail were calculated using data obtained from the HSIP database.
Source: HSIP Gold 2015.

Resource Name	Description of Dataset used in Analyses	Date of Access
Transmission Lines	Depict market significant existing and proposed electric power transmission lines in North America. Included lines generally have a capacity of greater than 69 kilovolts. Source: HSIP Gold 2015 – Ventyx	6/2015
Substations	Identifies existing and proposed substations in North American power transmission grids. Substations are facilities that switch, change, and/or regulate electric voltage. Source: HSIP Gold 2015 – Ventyx	6/2015
Rails	Represents the freight lines of the nation's railroad system. Source: HSIP Gold 2015 - Oak Ridge National Laboratory.	6/2015

Southern Methodist University (SMU) Data

Geothermal data for geothermal heat pumps and EGS were obtained from SMU.

Resource Name	Description of Dataset used in Analyses	Date of Download
Temperature at Depths	Information was obtained from SMU in 2011 in grid format. Depths provided were 3, 3.5, 4.5, 5.5, and 6.5 kilometers (km). Temperature –at-Depth Maps for the Conterminous U.S. and Geothermal Resource Estimates. David Blackwell, Maria Richards, Zachary Frone, Joseph Batir, Andres Ruzo, Ryan Dingwall, and Mitchell Williams, Geothermal Laboratory, SMU, Dallas, Texas 75275 Geothermal Resources Transactions, 2011.	2011
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).	6/27/2009
Heat Flow Gradient	Data were obtained from the 2004 Geothermal Map of the United States. (Dr. David Blackwell and Maria Richards, Geothermal Map of North America, AAPG Map, scale 1: 6,500,000, Product Code 423, 2004).	5/1/2009

U. S. Geological Survey (USGS)

Geothermal data for hydrothermal potential were obtained from USGS.

Resource Name	Description of Dataset used in Analyses	Date of Download
Identified Moderate and High Temperature Geothermal Systems of the Western United States including AK and HI	This dataset contains the locations of identified moderate (90 - 150° C) and high (> 150° C) temperature geothermal systems and associated reservoir volumes, temperatures, and estimated electric power generation potential. This is to be used to identify locations and characteristics of identified geothermal systems. http://certmapper.cr.usgs.gov/data/geothermal/western_us/spatial/shape/identifiedgeothermalsystems.zip	6/2015
Geothermal Favorability Map Derived from Logistic Regression Models of the Western United States	This dataset shows relative favorability for the presence of geothermal systems in the western United States. It is intended to highlight areas of elevated potential for the presence of undiscovered moderate (90 - 150° C) to high (> 150° C) temperature geothermal systems. It is not meant to be used to locate exact areas for exploration. http://certmapper.cr.usgs.gov/data/geothermal/western_us/spatial/shape/favorabilitysurface.zip	6/2015

ESRI Data

ESRI software, copyright 2001-2006

Resource Name	Description of Dataset used in Analyses	Date of Download
U.S. Highways (highways.sdc)	Used to calculate the approximate distance to the nearest graded road. The U.S. Highways dataset represents the major and minor highways of the United States. These include interstates, U.S. highways, state highways, major roads, and minor roads. This dataset is from the Census 2000 TIGER/Line files.	N/A

Appendix: RE Technology Basics

The following renewable energy technologies were evaluated for this analysis. They represent the most wide-spread 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.

Solar

Solar resource is typically characterized by the amount of solar energy striking a panel tilted at latitude over a given area and reported as a daily average. Solar radiation is measured in kilowatt-hours per square meter per day ($kWh/m^2/day$).

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.

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. A trough system uses 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. A 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. A 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.

For more information on solar technologies, visit: www.nrel.gov/learning/re_solar.html.

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.

Wind resource is typically characterized by wind speed (meters per second) at a given height. The resource data are selected based on the turbine size. For example, utility-scale turbines with hub heights ranging from 80-90 meters (m) generally reference the wind resource data at 80 m for initial screening.

For more information on wind technologies, visit: www.nrel.gov/learning/re_wind.html.

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.

A 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: forests, primary and secondary mills, and urban wood waste.

A 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 or forests, primary and secondary mills, and urban wood waste, cumulatively.

For more information on biomass technologies, visit: http://www.nrel.gov/learning/re_biomass.html.

Energy can also be generated by capturing methane and other emissions from landfills. For more information on EPA's Landfill Methane Outreach Program (LMOP) and landfill gas energy technologies, visit http://www.epa.gov/lmop/.

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 beneath the earth's surface —typically at depths less than three miles and mostly located in western states, Alaska, and Hawai'i— and the shallow ground near the Earth's surface that maintains a relatively constant temperature of 50°-60°F. Geothermal energy is unique, when compared to other renewable energy resources, in that it is more closely related to mineral or conventional fossil fuel resources, due to subsurface characterization.

Geothermal resource is typically characterized by temperature at a given depth, availability of water resources, and permeability of geologic layers.

Hydrothermal facilities use steam produced from existing reservoirs of hot water beneath the earth's surface to power electrical generators. The steam rotates a turbine that activates a generator, which produces the electricity.

Enhanced Geothermal facilities provide geothermal power by tapping into the Earth's geothermal resources that are otherwise not economical due to lack of water, location, or rock type. Enhanced geothermal systems (EGS) require engineering hydrothermal reservoirs in hot rocks for commercial use. The reservoirs are created by drilling wells into hot rock and fracturing the rock to enable a fluid to flow between the wells. The fluid flows along these fractures and other pathways, picking up heat from the rocks, and exits the reservoir via production wells. At the surface, the fluid passes through a power plant where electricity is generated. Upon leaving the power plant, the fluid is returned to the reservoir through injection wells to complete the circulation loop. EGS offers the chance to extend use of geothermal resources across more areas of the United States. Resource potential is screened based on temperature at depth.

A geothermal heat pump system taps into heat at Earth's surface. 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 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.

For more information on geothermal technologies, visit the DOE Energy Efficiency and Renewable Energy (EERE) Geothermal Technologies Program at: www1.eere.energy.gov/geothermal/ or www.nrel.gov/learning/re_geothermal.html.