U.S. DEPARTMENT OF ENERGY | Office of Indian Energy

Geospatial Analysis of Renewable Energy Technical Potential on Tribal Lands

E. Doris, A. Lopez, and D. Beckley
National Renewable Energy Laboratory

U.S. Department of Energy | Office of Indian Energy
1000 Independence Ave. SW, Washington DC 20585 | 202-586-1272
energy.gov/indianenergy | indianenergy@hq.doe.gov

Available electronically at www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: reports@adonis.osti.gov

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: www.ntis.gov/ordering.htm

U.S. DEPARTMENT OF ENERGY

energy.gov/indianenergy | indianenergy@hq.doe.gov

DOE/IE-0013 • February 2013

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post consumer waste.

Acknowledgments

This report is made possible by and at the direction of the DOE Office of Indian Energy Policy and Programs. The National Renewable Energy Laboratory (NREL) would like to thank our colleagues at NREL who reviewed this report for accuracy: Nate Blair, Billy Roberts, Gian Porro, Marguerite Kelly, and Ann Brennan. We would also like to thank our external partners who also reviewed provided insights throughout paper development: Paul Dearhouse, Royce Stewart, Tracey LeBeau, and Pilar Thomas. Finally, we'd like to thank Daniel Hillman for developing the summary tables of data and Rachel Sullivan for providing editorial support.

About the DOE Office of Indian Energy

The U.S. Department of Energy Office of Indian Energy Policy and Programs was established by Congress to provide Tribes, Alaska Native villages, and eligible tribal entities with technical and financial assistance that promotes energy development and energy infrastructure on tribal lands.

In direct response to the requests of Tribes and Alaska Native villages, the DOE Office of Indian Energy has designed key programs to provide Indian Country with the knowledge needed to make informed energy decisions—decisions with the power to help stabilize energy costs, enhance energy security, strengthen economic development and tribal energy infrastructure, and promote tribal self-determination.

By providing reliable, accurate information and expert technical assistance, the Office of Indian Energy empowers Indian Country to make decisions needed to bring about the next generation of energy development on their lands.

The office supports those decisions by offering technical support related to technology and project development, financial assistance, and real-time training. It also works to advance tribal visions for a sustainable energy future by promoting four key goal areas: project development, job creation, grid infrastructure, and energy security.

List of Abbreviations and Acronyms

BDT	bone dry tonne
BLM	Bureau of Land Management
CBI	Conservation Biology Institute
CSP	concentrating solar power
DNI	direct normal irradiance
DOE	U.S. Department of Energy
EGS	enhanced geothermal system
EPA	Environmental Protection Agency
ESRI	Environmental Systems Research Institute
FWS	Fish and Wildlife Service
GAP	Gap Analysis Project
kWh	kilowatt-hour
LULC	land use land cover
m	meter
MRLC	multi-resolution land cover
MW	megawatt
MWa	average megawatt [average number of megawatts over a specified amount of time (typically a year)]
MW_e	megawatts electric
MWh	megawatt-hour
NOAA	National Oceanographic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
PV	photovoltaic
ReEDS	Regional Energy Deployment System

RPS	renewable portfolio standard
SAM	System Advisor Model
SMU	Southern Methodist University
USFS	United States Forest Service
USGS	United States Geological Survey

Table of Contents

List of Figures

List of Tables

1 Purpose and Summary

This paper uses an established geospatial methodology to estimate the technical potential for renewable energy on tribal lands for the purpose of allowing Tribes to prioritize the development of renewable energy resources either for community-scale on-tribal-land use or for revenue-generating electricity sales. A graphical summary of the report and its findings is available: http://www.nrel.gov/docs/fy13osti/57048.pdf.

Geospatial methodology is an approach to analyzing information that incorporates data that has a geographic component and allows for a more refined analysis of technical potential for all Tribes by parsing it to individual tribal lands. Technical potential is narrowing of resource potential to exclude topographic constraints and land-use constraints while taking into account system performance (for a more detailed definition, see the Introduction/Background section).

Although this analysis provides insight into the potential for renewable energy development on tribal lands, further identification and removal of barriers for tribal renewable energy development and the processes for overcoming them is needed to lead to actual increases in renewable energy generation on tribal lands. The next step for Tribes that wish to pursue projects is to determine the market or developable potential of renewable energy. This includes assessing broader tribal interests in development (e.g., scale of project, purpose of project, cultural sensitivity avoidance); understanding the energy environment in which the project would function as a way of assessing potential project viability and economics; and working with the local utility and regulatory authorities to understand renewable energy needs.

The DOE Office of Indian Energy Policy and Programs offers a number of resources to support the development of renewable energy resources, including a detailed energy resource library containing documents that provide information on project development, training on renewable technology attributes, a step-by-step process for project development and financing options, and the provision of technical assistance to Tribes in need of expertise in project development and financing. Information on available assistance can be found on the DOE Office of Indian Energy website: www.energy.gov/indianenergy.

Only a few nationwide tribal examples exist to extrapolate successful renewable energy development models, and this report intends to provide Tribes with basic information regarding the development potential for renewable energy—biomass, geothermal, hydroelectric, solar, and wind—on tribal lands. It provides detailed renewable energy potential information by tribal territory and resource throughout the United States in order to help Tribes identify areas where development may be an option, and where tribal or private investment in renewable energy may assist in achieving a Tribe's economic development, energy savings, or self-sufficiency goals.

Overall, the analysis shows that the technical potential on tribal lands is about 6% of the total national technical generation potential (Table S-1). This is disproportionately larger than the 2% tribal lands in the United States, indicating an increased potential density for renewable energy development on tribal lands.

Table S-1. Summary of Tribal Technical Potential by Capacity and Generation

Technology	Tribal Capacity[a] Potential[b] (MW)	National Capacity Potential[c] (MW)	Tribal Generation Potential (MWh)	National Generation[a] Potential (MWh)	% of National Capacity	% of National Generation
Solar PV (Utility-Scale, Rural)	6,888,339	152,973,829	14,322,522,713	280,613,216,903	4.5%	5.1%
Solar PV (Utility-Scale, Urban)	8,199	1,217,699	17,578,618	2,231,693,746	0.7%	0.8%
Solar CSP	1,818,185	38,066,401	6,139,851,743	116,146,244,587	4.8%	5.3%
Wind (80 m height, >=30% GCF)	374,505	10,954,759	1,146,044,229	32,784,004,656	3.4%	3.5%
Geothermal (EGS)	763,252	3,975,735	6,017,487,000	31,344,696,024	19.2%	19.2%
Geothermal (Hydrothermal)	641	30,033	5,050,724	236,780,000	2.1%	2.1%
Biomass (Solid)	551	50,707	4,340,642	399,774,091	1.1%	1.1%
Biomass (Gaseous)	85	11,232	673,465	88,551,445	0.8%	0.8%
Hydropower	1,687	60,000	7,390,196	258,953,000	2.8%	2.9%
Total[b]	9,855,444	207,340,394	27,660,939,330	464,103,914,451	4.8%	6.0%

[a] Capacity is the nameplate capacity of a power plant. Generation is the amount of MWh produced given average run times.

[b] Technical potential calculated for each technology individually and does not account for overlap (i.e., the same land area may be identified with potential for wind and solar, and would be counted twice in the total). Some technologies may be compatible with mutual development.

[c] Lopez, A. et al. (2012). *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis*. NREL/TP-6A20-51946. Golden, CO: National Renewable Energy Laboratory.

2 Introduction/Background

While other estimates of renewable energy potential on tribal lands exist, the strength of this style of estimation of resources is the use of up-to-date geospatial data for a more accurate representation of available resources. This is the first paper of its kind to use geospatial analysis to estimate the technical potential of renewable energy development on tribal lands. Technical potential is one of four levels of potential for renewable energy, as defined in Figure 1.

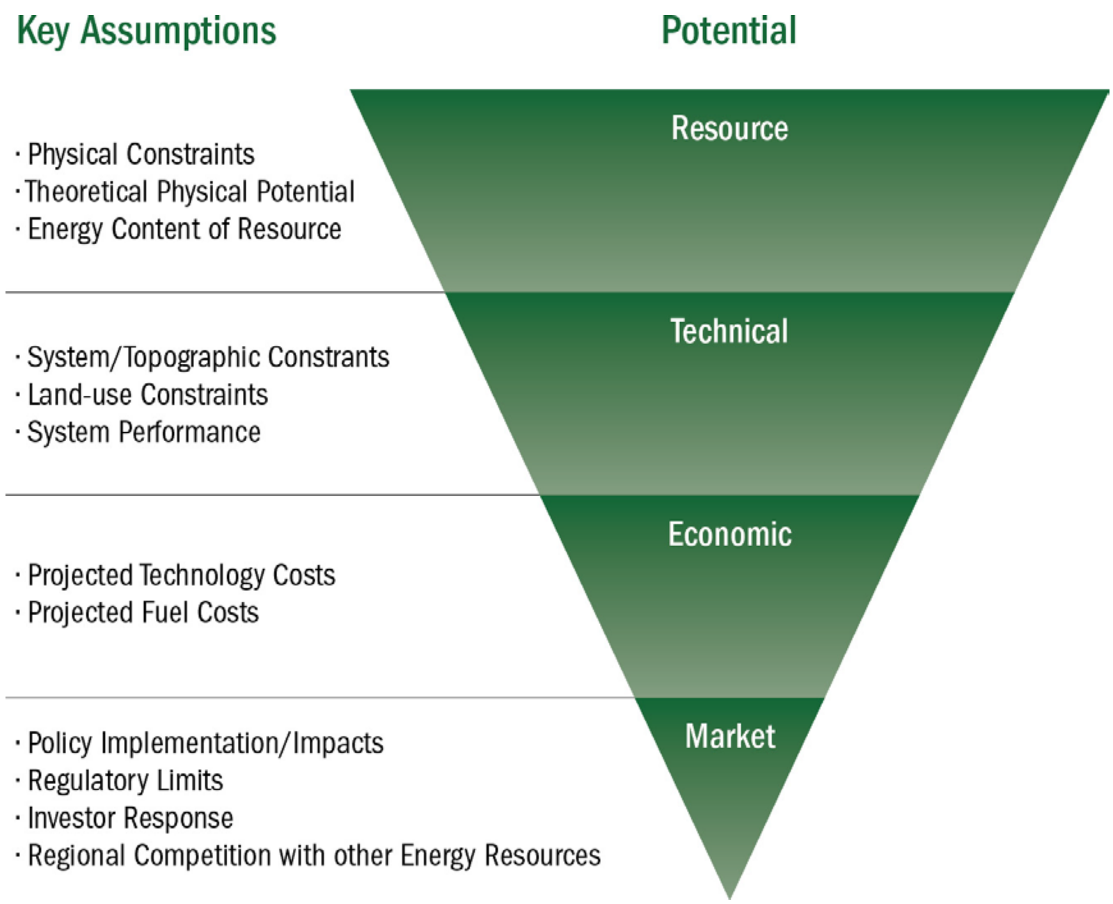

Figure 1. Levels of renewable energy potential defined

Source: Lopez et al. 2012, adapted from the DOE Office of Energy Efficiency and Renewable Energy (EERE) 2006

The renewable resources included in this report are described as follows in the remainder of this section. With the exception of enhanced geothermal systems, the scope of this work includes currently commercially available technologies within the definition of technical potential.

- **Biopower**. Biomass has been used for electric power generation for many years. It can be a cost-effective, carbon-neutral dispatchable source of electrical power. Most biopower plants use direct-fired systems to generate electricity from biomass. They burn bioenergy feedstocks directly to produce steam. This steam drives a turbine, which turns a generator that converts the power into electricity. In some biomass industries, the spent steam from the power plant is also used for manufacturing processes or to heat buildings. Such combined heat and power systems greatly increase overall energy efficiency. Types of biomass include wood from various sources (beetle kill, slash, lumber waste), agricultural residues, animal and human waste (methane), and municipal solid waste and landfill gas.

- **Geothermal**. Geothermal technologies use heat from the Earth. Geothermal is a highly efficient method of providing electricity generation. High-temperature geothermal is ideal for power plant production levels, but low-temperature heat pumps can provide heating and cooling energy in any part of the United States. Lower-temperature resources are best suited for heat applications. Geothermal technologies exist commercially for either small-scale (distributed) or large-scale (central) electricity generation. As of 2012, 248 U.S. geothermal systems produce 9,057 mean megawatts of electricity (MWe). There are an estimated 30,033 MWe of undiscovered geothermal resources in the United States.
- **Hydropower**. Hydroelectricity refers to electricity generated through the use of the gravitational force of falling or flowing water, called hydropower. Both large and small-scale power producers can use hydropower technologies to produce clean electricity.
- **Concentrating Solar Power**. Concentrating solar power (CSP) technologies use mirrors to reflect and concentrate sunlight onto receivers that collect solar energy and convert it to heat. This thermal energy can then be used to produce electricity via a steam turbine or heat engine that drives a generator. While CSP offers a utility-scale, firm, dispatchable renewable energy option that can help meet demand for electricity, it is most economical in the southwestern United States. Factors that influence project economics are the cost of the technology, the quality of the solar resource, and the cost of the energy being displaced. CSP systems can be successfully installed on landfills, brownfields, and greenfields, with minimal disturbance to native vegetation and wildlife. Types of CSP systems include linear concentrator, dish/engine, power tower, and thermal storage.
- **Solar PV**. Photovoltaic (PV) technologies produce electricity directly from the energy of the sun. Small PV can provide electricity for homes, businesses, and remote power needs. Larger PV systems provide more electricity for contribution to the electric power system. PV technologies work in all parts of the United States, but economics are dependent on technology cost, quality of solar resource, and cost of energy being displaced. Flat plate is the most common PV array design, which uses flat-plate PV modules or panels that can be fixed in place or designed to track the movement of the sun. An off-grid, flat-plate solar PV system would be useful for remote locations or for self-sufficiency in the event of a power interruption. Concentrator PV systems use less solar cell material than other PV systems because they make use of relatively inexpensive materials such as plastic lenses and metal housings to capture the solar energy shining on a fairly large area and focus that energy onto a smaller area—the solar cell.
- **Wind**. Wind energy technologies use the kinetic energy in wind for practical purposes such as generating electricity, charging batteries, pumping water, and grinding grain. Most wind energy technologies can be used as stand-alone applications, connected to a utility power grid, or even combined with a PV system. Wind energy today is cost competitive in many locations throughout the United States. Utility-scale wind consists of a large number of turbines that are usually installed close together to form a wind farm that provides grid power. Several electricity providers use wind farms to supply power to their customers. Stand-alone turbines are typically used for water pumping or communications. However, homeowners and farmers in windy areas can also use small wind systems to generate electricity.

For more information on renewable energy basics for Tribes, please search for "DOE Office of Indian Energy" at http://www.nterlearning.org.

Technical potential may not reflect the developable potential because it does not incorporate technology costs, competing land uses, transmission and infrastructure availability, or the policy, investor, or energy competitive environments. For Tribes, specific barriers can include a lack of:

- Replicable, successful examples of renewable energy development on tribal lands
- Clear ownership and tax equity structure options
- Access to transmission lines for movement of generated electricity
- Active markets for the buying and selling of renewable energy (often state policy driven through the use of renewable portfolio standards, or RPS)

While this report focuses on the identification of technical potential, there are resources for further understanding the market and economic potential for, and developing renewable energy resources on tribal lands at www.energy.gov/indianenergy, including a development document library, technical assistance, and education.

3 Analysis Methodology

The basic methodology for determining the technical potential on tribal lands is to:

1) Determine the land area of the tribal lands
2) Estimate how much renewable resource exists within those areas
3) Estimate the amount of electricity that could possibly be produced from that land area, based on currently available technology for converting that resource into electricity.

Data on the area of tribal lands was downloaded from the Department of the Interior, Bureau of Indian Affairs and is dated 1999. This is the most recent and comprehensive database of federally recognized tribal lands. Due to lack of data resolution, only the exclusions listed in Appendix 1 are removed from the land within tribal areas. This analysis does not include removal of culturally sensitive areas or areas already in use that would not be appropriate for development.

The detailed methodology for determining the available resource, as well as the technical capabilities of the resource to electricity conversion technologies, is described in detail for each resource below.

Biopower

Biopower is the only technology analyzed using an alternative dataset than what was used in Lopez et al. 2012. The dataset used in Lopez et al. 2012 was county-based; it was determined that the resolution was too coarse for the relatively small tribal lands. Instead, land cover-based disaggregated estimates from the Biopower Atlas (http://maps.nrel.gov/biopower) are used. An area-weighted analysis was performed between the disaggregated datasets and the tribal lands to produce the total amount of gaseous and solid biomass on each tribal land.

Total estimated technical potential for gaseous biomass generation was estimated using 4.7 megawatt-hours (MWh)/tonne of CH_4 (Lopez et al. 2012). This can be expressed as:

$$Biogasgen_t = \sum_{k \in K} \frac{AI_{k,t}}{A_t} \cdot P_k \cdot C$$

where

t = Tribal land

$Biogasgen_t$ = Biogas generation on tribal land *t* (MWh)

$AI_{k,t}$ = Area of intersect between land cover polygon *k* and tribal land *t*

A_t = Area of tribal land *t*

k = Land-cover polygon

K = Set of land-cover polygons

P_k = CH_4 potential resource for land-cover polygon *k* (tonnes)

C = Biogas CH_4 conversion to energy (4.7 MWh/tonne CH_4)

Estimated capacity for gaseous biomass was estimated by backing out the time component of the generation conversion and assuming a standard capacity factor of 90%. This can be expressed as:

$$Biogascap_t = \frac{Biogasgen_t}{CFbio \cdot 8760hr}$$

where

t = Tribal land

$Biogascap_t$ = Biogas capacity on tribal land *t* (MW)

CFbio = Capacity factor for biopower

Total estimated generation for solid biomass was estimated using 1.1 MWh/bone dry tonne (BDT) (Lopez et al. 2012). Expressed as:

$$Biosolidgen_t = \sum_{k \in K} \frac{AI_{k,t}}{A_t} \cdot P_k \cdot C$$

where

t = Tribal land

$Biosolidgen_t$ = Solid biomass generation on tribal land *t* (MWh)

$AI_{k,t}$ = Area of intersect between land cover polygon *k* and tribal land *t*

A_t = Area of tribal land *t*

k = Land-cover polygon

K = Set of land-cover polygons

P = Bone dry tonne potential resource

C = Solid biomass conversion to energy (1.1 MWh/bone dry tonne)

Estimated capacity for solid biomass was estimated by backing out the time component of the generation conversion and assuming a standard capacity factor of 90%. This can be expressed as:

$$Biosolidcap_t = \frac{Biosolidgen_t}{CFbio \cdot 8760hr}$$

where

t = Tribal land

$Biosolidcap_t$ = Solid biomass capacity in tribal land t (MW)

AI = Area of intersect (in this case, between resource and tribal land)

P = Bone dry tonne potential resource

C = Solid biomass conversion to energy (1.1 MWh/bone dry tonne)

CFbio = Capacity factor for biopower

Geothermal

Two types of geothermal systems were included in this analysis: undiscovered hydrothermal and enhanced geothermal system (EGS). Undiscovered hydrothermal system estimates were derived from Williams et al. 2009. The estimates were generated using a logistical regression model of the western United States. The model determined favorability and estimated a power density, which was used to determine the potential capacity, expressed as:

$$Hydrothermcap_t = \sum_{i \in I_t} A_i \cdot PD_i$$

where

t = Tribal land

$Hydrothermcap_t$ = hydrothermal capacity in tribal land *t* (MW)

i = Distinct grid-cell

I_t = Set of grid-cells that exist in tribal land *t*

A_i = Square kilometers of available land in grid-cell *i*

PD_i = Power density for grid-cell *i*

Undiscovered hydrothermal generation was estimated using:

$$Hydrothermgen_t = Hydrothermcap_t \cdot CFht \cdot 8760hr$$

where

t = tribal land

$hydrothermgen_t$ = Hydrothermal generation in tribal land *t* (MWh)

$hydrothermcap_t$ = Hydrothermal capacity in tribal land *t* (MW)

CFht = Capacity factor for hydrothermal

EGS technical potential estimates were calculated using temperature at depth data from the Southern Methodist University (SMU) Geothermal Laboratory. The data was first filtered to remove areas deemed unlikely for development (see Appendix 1). Next, the data was limited to areas intersecting tribal lands. Then, using the methodology described in Lopez et al. 2012 to determine optimal depth, capacity was estimated and can be expressed as:

$$EGScap_t = \sum_{i \in I_t} A_i \cdot PD_i$$

where

t = Tribal land

$EGScap_t$ = EGS capacity in tribal land *t* (MW)

i = Distinct grid-cell

I_t = Set of grid-cells that exist in tribal land *t*

A_i = Square kilometers of available land in grid-cell *i*

PD_i = Power density for grid-cell *i*

Using the same optimal depth, technical potential generation was estimated and can be expressed as:

$$EGSgen_t = EGScap_t \cdot CFegs \cdot 8760hr$$

where

t = tribal land

$EGSgen_t$ = EGS generation in tribal land *t* (MWh)

$EGScap_t$ = EGS capacity in tribal land *t* (MW)

CFegs = Capacity factor for EGS

Hydropower

Hydropower in this study is defined as low power (<1 MWa[1]) or small hydro (>= 1 MWa and <= 20 MWa). Hydropower source point locations with potential average capacity were taken from Hall et al. 2006. The source points were a result of a feasibility study and development model; thus, no action was required on NREL's part to determine technical feasibility.

[1] Average megawatt capacity; assumes 50% capacity factor.

To estimate technical potential capacity, the hydropower source points were intersected with tribal lands, summed by Tribe and doubled. The doubling backs out the assumed capacity factor in the average capacity. Technical potential capacity can be expressed as:

$$Hydrocap_t = \sum_{j \in J_t} \frac{Pcapa_j}{CFhydro}$$

where

t = Tribal land

$Hydrocap_t$ = Hydropower capacity in tribal land *t* (MW)

$Pcapa_j$ = Hydropower average capacity for source point *j* (MWa)

j = Hydropower source point

J_t = Set of hydropower source points in tribal land *t*

CFhydro = Capacity factor for hydropower

Technical potential generation was estimated by maintaining the existing capacity factor in the average capacity and adding the time component, expressed as:

$$Hydrogen_t = \sum_{j \in J_t} Pcapa_j \cdot 8760hr$$

where

t = Tribal land

$Hydrogen_t$ = Hydropower generation in tribal land *t* (MWh)

$Pcapa_j$ = Hydropower average capacity for source point *j* (MWa)

j = Hydropower source point

J_t = Set of hydropower source points in tribal land *t*

Concentrating Solar Power

CSP is a utility-scale solar power plant in which the solar heat energy is collected in a central location. To get a general sense of CSP potential, CSP resource is analyzed. CSP resource is typically measured using direct normal irradiance (DNI)[2] as kilowatt-hours (kWh) per square meter per day (kWh/m^2/day). In this analysis, we consider viable only areas with DNI greater than or equal to 5 kWh/m^2/day (Lopez et al. 2012).

Further reducing developable land was needed to ensure a more realistic potential. The first step was to remove areas with slope greater than or equal to 5%. Next, areas with land-use/land-cover deemed unlikely for development were excluded (see Appendix). Last, areas were constrained to tribal lands, and a minimum contiguous area threshold of 1 square kilometer was imposed to ensure a utility-scale system.

With developable lands defined, a specific CSP system was defined and capacity and generation estimated. The system chosen was a trough, dry-cooled one with six hours of storage and a solar multiple of 2.[3] The assumed system power density was 32.8 megawatts per kilometer squared (Lopez et al. 2012). Technical potential capacity was expressed as:

$$CSPcap_t = \sum_{i \in I_t} A_i \cdot PD$$

where

t = Tribal land

$CSPcap_t$ = CSP capacity in tribal land *t* (MW)

i = Distinct grid-cell

I_t = Set of grid-cells that exist in tribal land *t*

A_i = Square kilometers of available land in grid-cell *i*

PD = Power density (32 MW/km^2)

To estimate generation potential, the DNI resource was divided into five classes. Capacity factors were taken from Lopez et al. 2012. Technical potential generation was then calculated and can be expressed as:

---

[2] The amount of solar radiation received per unit area by a surface that is always held perpendicular (or normal) to the rays that come in a straight line from the direction of the sun at its current position in the sky.

[3] The field aperture area expressed as a multiple of the aperture required to operate the power cycle at its design capacity.

$$CSPgen_t = \sum_{i \in I_t} A_i \cdot PD \cdot CFcsp_i \cdot 8760hr$$

where

t = Tribal land

$CSPgen_t$ = CSP generation in tribal land *t* (MWh)

i = Distinct grid-cell

I_t = Set of grid-cells that exist in tribal land *t*

A_i = Square kilometers of available land in grid-cell *i*

$CFcsp_i$ = Capacity factor for CSP for grid-cell *i*

PD = Power density (32 MW/km^2)

Solar PV

The technical potential for solar utility-scale PV was first determined by eliminating areas deemed unlikely for development. These areas include those of environmental concern and national parks (a full list is included in Appendix 1). Note that the exclusions do not include potentially culturally sensitive areas as there is not currently a comprehensive dataset of those sites available. Next, the available land within each tribal boundary was separated into urban and rural classifications. This allows for a greater understanding of the geographic quality of PV potential (i.e., proximity to areas where the electricity might be used).

Urban available lands were constrained to eliminate impervious surfaces. This has the effect of removing roads, parking lots, and buildings, leaving only urban open space. The urban open spaces were further constrained to eliminate contiguous areas less than 18,000 square meters; this ensures the total system size is large enough to be considered utility scale.[4]

Rural available lands were constrained to eliminate areas less than 1 square kilometer. The area constraint reduces highly fragmented parcels.

The final step in calculating technical potential required a specific PV system. The PV system chosen was a 1-axis tracking collector with the axis of rotation aligned north-south at 0° tilt from the horizontal. Assuming a power density of 48 MW per square kilometer (Lopez et al. 2012), the technical potential capacity was estimated and can be expressed as:

[4] Depending on the PV system, 18,000 m^2 is roughly a 1-MW system.

$$PVcap_t = \sum_{i \in I_t} A_i \cdot PD$$

where

t = Tribal land

$PVcap_t$ = PV capacity in tribal land *t* (MW)

i = Distinct grid-cell

I_t = Set of grid-cells that exist in tribal land *t*

A_i = Square kilometers of available land in grid-cell *i*

PD = Power density (48 MW/km^2)

To determine technical potential generation, capacity factors were estimated. State-level capacity factors were taken from Lopez et al. 2012. Technical potential generation can be expressed as:

$$PVgen_t = \sum_{i \in I_t} A_i \cdot PD \ \cdot CFpv_i \cdot 8760hr$$

where

t = Tribal land

$PVgen_t$ = PV generation in tribal land t (MWh)

i = Distinct grid-cell

I_t = Set of grid-cells that exist in tribal land *t*

CFpv = Capacity factor for PV for grid-cell *i*

Wind

Wind was analyzed at 80 meters (m) above the earth's surface. Only windy areas greater than or equal to an annual average gross capacity factor[5] of 30% were included in the analysis. The gross capacity factors used in the analysis were developed by AWS Truepower; they represent typical utility-scale wind turbine power curves.

The resource areas were filtered to remove areas deemed unlikely for development, including: national parks, federally protected lands, and water features. For a full list of exclusions, see Appendix 1.

Technical potential capacity for wind was estimated assuming 5 MW/km^2 (Lopez et al. 2012) and can be expressed as:

$$Windcap_t = \sum_{i \in I_t} A_i \cdot PD$$

where

t = Tribal land

$Windcap_t$ = Wind capacity in tribal land *t* (MW)

i = Distinct grid-cell

I_t = Set of grid-cells that exist in tribal land *t*

A_i = Square kilometers of available land in grid-cell *i*

PD = Power density (5 MW/km^2)

Technical potential for wind generation was estimated assuming 15% energy losses (Lopez et al. 2012) and can be expressed as:

$$Windgen_t = \sum_{i \in I_t} A_i \cdot PD \cdot CFwind_i \cdot 8760hr \cdot loss$$

[5] Gross capacity factor does not include plant downtime, parasitic power, or other factors that would be included to reduce output to the "net" capacity factor. For more information on capacity factors, see http://www.eia.gov/tools/faqs/faq.cfm?id=187&t=3.

where

t = Tribal land

$Windgen_t$ = Wind generation on tribal land *t* (MWh)

i = Distinct grid-cell

I_t = Set of grid-cells that exist in tribal land *t*

$CFwind_i$ = Capacity factor for wind for grid-cell *i*

loss = 15% reduction from gross to net generation

4 Results

The methodology results in an understanding of the technical potential for renewable energy on tribal lands by resource. It provides a starting point for understanding where Tribes could prioritize the development of renewable energy resources, either for community-scale on-tribal-land use or for revenue-generating electricity sales.

Findings indicate that while tribal lands comprise 2% of U.S. lands, technical potential on tribal lands comprises 4.8% of the total national U.S. technical capacity potential for renewable energy and 6% of the total generation, varying by resource (see Table 4-1). Solar photovoltaics (both urban and rural), concentrated solar power, and wind have the largest technical potential of the renewable resources. Geographically, tribal lands in the Southwest have the greatest percentage of the potential. The following subsections provide more detail on the technical potential by renewable energy resource and tribal land.

Table 4-1. Summary of Tribal Technical Potential by Capacity and Generation

Technology	Tribal Capacity Potential[a] (MW)	National Capacity Potential[a] (MW)	Tribal Generation Potential[a] (MWh)	National Generation Potential[a] (MWh)	% of National Capacity	% of National Generation
Solar PV (Utility-Scale, Rural)	6,888,339	152,973,829	14,322,522,713	280,613,216,903	4.5%	5.1%
Solar PV (Utility-Scale, Urban)	8,199	1,217,699	17,578,618	2,231,693,746	0.7%	0.8%
Solar CSP	1,818,185	38,066,401	6,139,851,743	116,146,244,587	4.8%	5.3%
Wind (80 m height, >=30% GCF)	374,505	10,954,759	1,146,044,229	32,784,004,656	3.4%	3.5%
Geothermal (EGS)	763,252	3,975,735	6,017,487,000	31,344,696,024	19.2%	19.2%
Geothermal (Hydrothermal)	641	30,033	5,050,724	236,780,000	2.1%	2.1%
Biomass (Solid)	551	50,707	4,340,642	399,774,091	1.1%	1.1%
Biomass (Gaseous)	85	11,232	673,465	88,551,445	0.8%	0.8%
Hydropower	1,687	60,000	7,390,196	258,953,000	2.8%	2.9%
Total[b]	9,855,444	207,340,394	27,660,939,330	464,103,914,451	4.8%	6.0%

[a] Lopez, A. et al. (2012). *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis.* NREL/TP-6A20-51946. Golden, CO: National Renewable Energy Laboratory.

[b] Technical potential calculated for each technology individually and does not account for overlap (i.e., the same land area may be identified with potential for wind and solar, and would be counted twice in the total). Some technologies may be compatible with mutual development.

Biomass

The total technical potential for electricity generation from solid biomass on tribal lands is about 399 million MWh, or about 1.1% of the total U.S. technical potential. The top three tribal lands in terms of potential generation are Nez Perce (336,000 MWh), Lake Traverse (Sisseton) (300,000 MWh), and Yakama (274,000 MWh). The top 25 tribal lands by technical potential for biopower from solid (Table 4-2) and gaseous (Table 4-3) biomass resources are below. An alphabetical list of all technical potentials by tribal lands is in Appendix 2. Developable potential of biomass resources is often limited by the market costs of transporting the fuel.

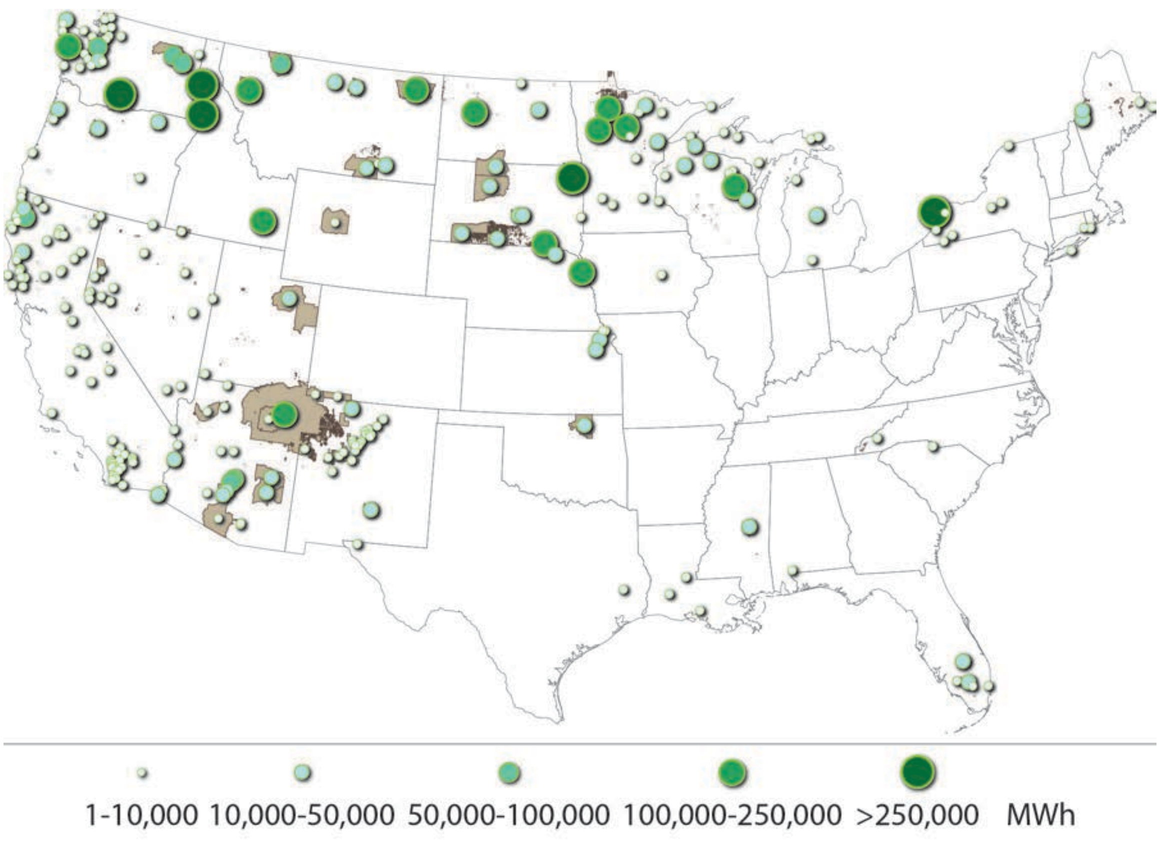

Figure 2. Tribal lands biomass generation potential

Table 4-2. Top 25 Tribal Lands by Technical Potential for Biopower Generation from Solid Residues

Tribal Land	State	Biopower from Solid Residues[a] (MWh)	Biopower from Solid Residues (MW)
Nez Perce	ID	336,781	43
Lake Traverse (Sisseton)	SD, MN, ND	300,466	38
Yakama	WA	274,750	35
Coeur d'Alene	WA,ID	264,737	34
Menominee	WI	246,145	31
Quinault	WA	161,549	20
Fort Peck	MT	159,234	20
Leech Lake	MN	158,657	20
Omaha	IA, NE	143,838	18
White Earth	MN	138,785	18
Red Lake	MN	124,764	16
Flathead	MT	123,572	16
Yankton	NE, SD	114,257	14
Fort Berthold	ND	109,151	14
Navajo	NM, UT, AZ, CO	103,018	13
Fort Hall	ID	101,896	13
Blackfeet	MT	87,202	11
Winnebago	IA, NE	76,709	10
Ho-Chunk	WI	68,939	9
Spokane	WA	66,932	8
Colville	WA	59,616	8
Hoopa Valley	CA	55,748	7
Devils Lake Sioux	ND	46,079	6
Crow	WY, MT	43,001	5
Fond du Lac	MN	41,847	5

[a] Solid residues are represented by forest, crop, primary mill, and urban wood residues. Generation estimated assuming 1.1 MWh/bone dry tonne of residue.

Table 4-3. Top 25 Tribal Lands by Technical Potential for Biopower Generation from Gaseous Residues

Tribal Land	State	Biopower from Gaseous Residues[a] (MWh)	Biopower from Gaseous Residues (MW)
Tuscarora	NY	440,925	56
Yawapa Apache	AZ	74,323	9
Port Madison	WA	61,835	8
Salt River	AZ	59,395	8
Cocopah	AZ, CA	25,403	3
Navajo	NM, UT, AZ, CO	1,755	0
Lone Pine Rancheria	CA	888	0
Osage	OK	659	0
Gila River	AZ	459	0
Puyallup	WA	427	0
Uintah and Ouray	UT	335	0
Yakama	WA	329	0
Isabella (Sag Chip)	MI	320	0
Tohono O’odham	AZ	296	0
San Xavier (TON)	AZ	293	0
Agua Caliente	CA	268	0
Flathead	MT	262	0
Oneida (West)	WI	232	0
Crow	WY, MT	229	0
Fort Hall	ID	210	0
Wind River	WY	183	0
White Mountain	AZ	182	0
Isleta Pueblo	NM	169	0
Tulalip	WA	164	0
Southern Ute	NM, CO	144	0

[a] Gaseous residues are represented by landfill and domestic wastewater residues. Generation estimated assuming 4.7 MWh/tonne of CH_4 produced by the residues.

Geothermal

The total technical potential on tribal lands for hydrothermal geothermal resource capacity is about 236 million MWh, or about 2.1% of the total U.S. technical potential. The top three tribal lands in terms of potential generation are Navajo (597,000 MWh), Tohono O'odham (510,000 MWh), and Warm Springs (405,000 MWh). Table 4-4 lists the top 25 tribal lands in terms of the technical potential of hydrothermal generation with enhanced geothermal systems (EGS, a less commercially viable geothermal option) for reference. A full list of technical potential by tribal land is listed in Appendix 2. Geothermal resources are widely distributed across tribal lands, with 196 distinct lands having technical potential.

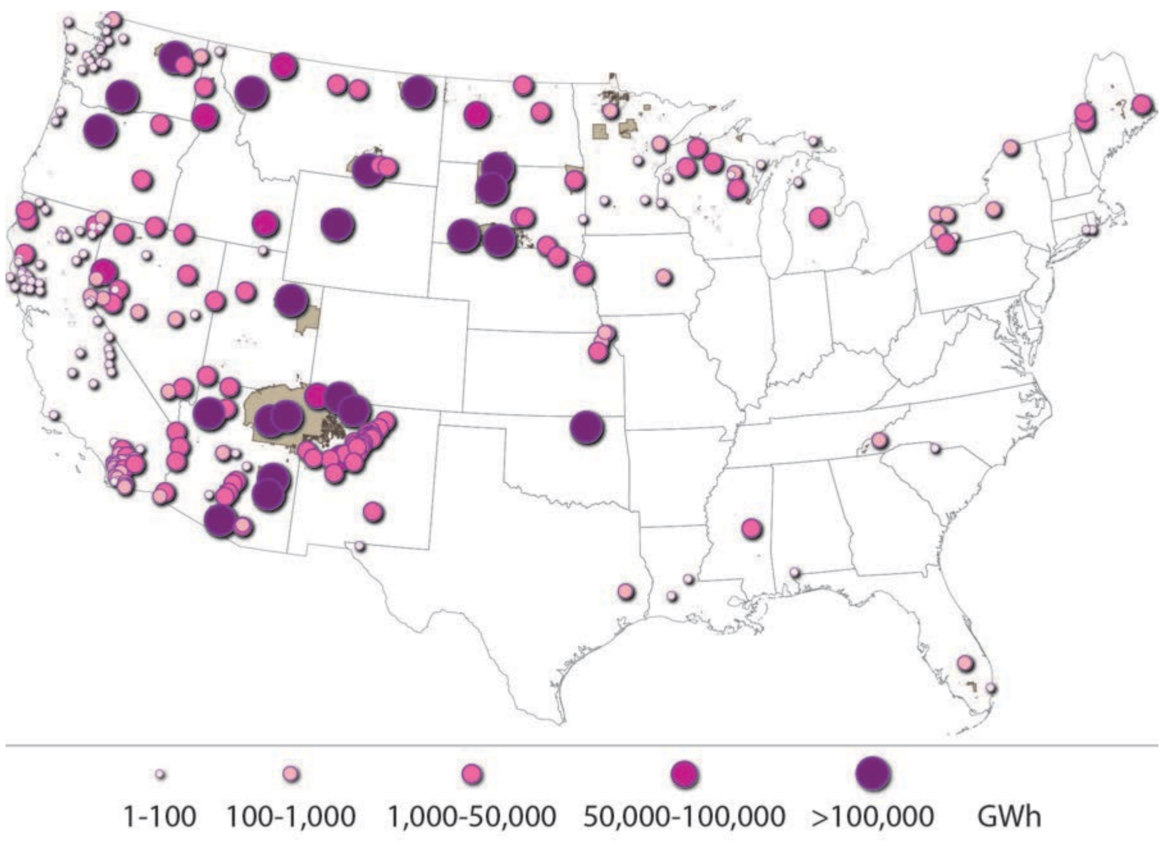

Figure 3. Tribal lands geothermal (EGS and hydrothermal) generation potential

Table 4-4. Top 25 Tribal Lands by Technical Potential for Hydrothermal Geothermal Generation

Name	State	Unidentified Hydrothermal Potential Annual Generation (MWh)	Unidentified Hydrothermal Potential Installed Capacity (MW)	Enhanced Geothermal Systems Potential Annual Generation (MWh)	Enhanced Geothermal Systems Potential Installed Capacity (MW)
Navajo	NM, UT, AZ, CO	597,545	76	1,263,774,000	160,296
Tohono O'odham	AZ	510,243	65	323,796,000	41,070
Warm Springs	OR	405,953	51	102,311,000	12,977
Pyramid Lake	NV	324,409	41	58,397,000	7,407
Walker River	NV	246,481	31	41,959,000	5,322
Hualapai	AZ	210,076	27	121,721,000	15,439
Southern Ute	NM, CO	188,245	24	121,248,000	15,379
San Carlos	AZ	179,374	23	195,137,000	24,751
Fort Hall	ID	179,275	23	78,603,000	9,970
Duck Valley	NV, ID	164,004	21	40,642,000	5,155
Yakama	WA	155,549	20	127,957,000	16,230
Flathead	MT	151,999	19	122,383,000	15,523
Jicarilla Apache	NM, CO	143,397	18	112,481,000	14,267
Fort Peck	MT	120,159	15	216,203,000	27,423
White Mountain	AZ	119,240	15	150,687,000	19,113
Lake Traverse (Sisseton)	SD, MN, ND	88,772	11	35,762,000	4,536
Uintah and Ouray	UT	78,807	10	347,054,000	44,020
Colville	WA	70,390	9	127,342,000	16,152
Blackfeet	MT	60,031	8	95,089,000	12,061
Nez Perce	ID	51,827	7	72,943,000	9,252
Wind River	WY	47,999	6	174,985,000	22,195
Taos Pueblo	NM	46,205	6	11,124,000	1,411
Zuni Pueblo	NM, AZ	44,632	6	42,857,000	5,436
Isleta Pueblo	NM	44,203	6	23,479,000	2,978
Goshute	NV, UT	44,152	6	12,898,000	1,636

Hydropower

The total technical potential on tribal lands for generation from hydropower resource is about 13 million MWh, or about 5.1% of the total U.S. technical potential. The top three tribal lands in terms of potential generation are Nez Perce (2.6 million MWh), Flathead (1.5 million MWh), and Yakama (1.2 million MWh). A full list of technical potential by tribal land is listed in Appendix 2.

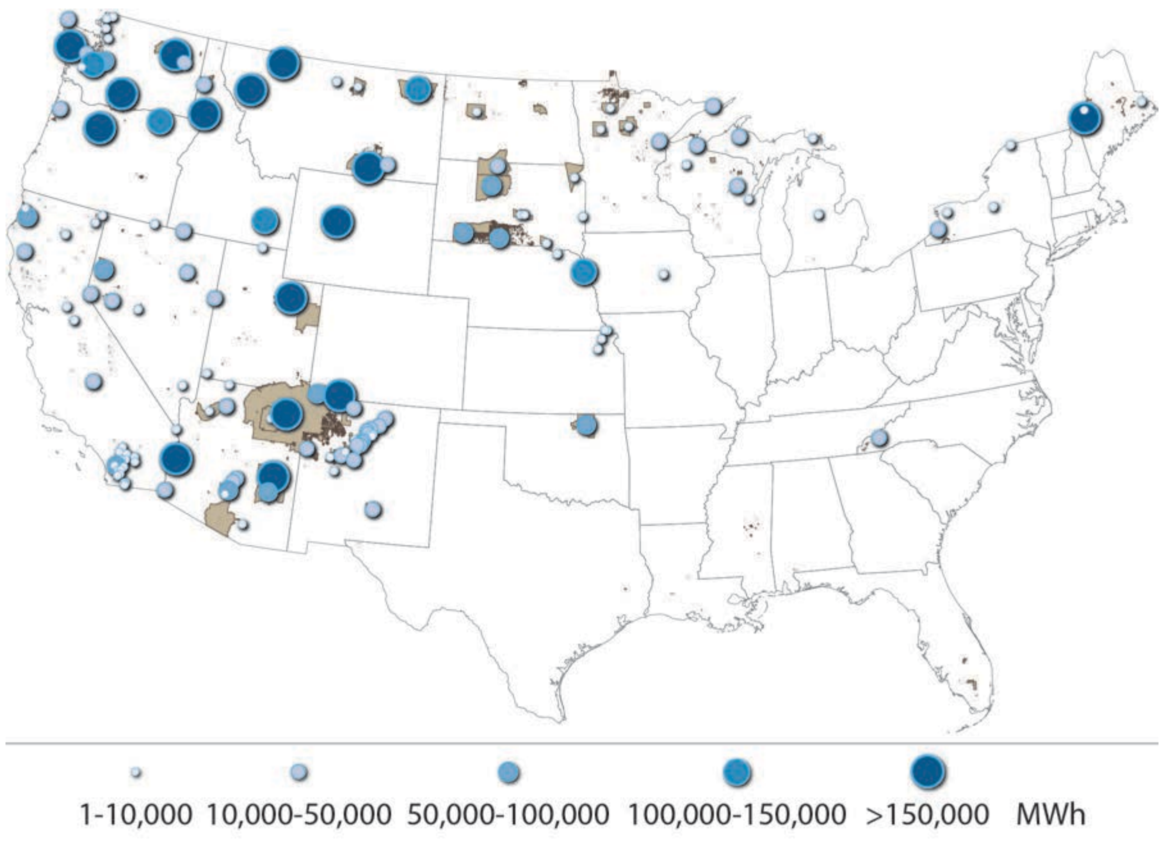

Figure 4. Tribal lands hydropower generation potential

Table 4-5. Top 25 Tribal Lands by Technical Potential for Hydropower Generation

Tribal Land	State	Hydropower Generation Potential (MWh)	Hydropower Capacity Potential (MW)
Nez Perce	ID	1,445,260	330
Flathead	MT	816,341	186
Yakama	WA	669,640	153
Blackfeet	MT	445,893	102
Uintah and Ouray	UT	442,276	101
Navajo	NM, UT, AZ, CO	369,000	84
Wind River	WY	350,640	80
Quinault	WA	339,978	78
Colville	WA	247,936	57
Southern Ute	NM, CO	243,721	56
Penobscot	ME	189,260	43
Warm Springs	OR	130,737	30
White Mountain	AZ	115,435	26
Colorado River	AZ, CA	106,505	24
Crow	WY, MT	89,049	20
Fort Hall	ID	70,593	16
Omaha	IA, NE	61,961	14
Fort Peck	MT	57,645	13
Nisqually	WA	57,594	13
Umatilla	OR	57,403	13
San Carlos	AZ	49,442	11
Winnebago	IA, NE	48,821	11
Gila River	AZ	47,987	11
Cheyenne River	SD	47,065	11
Muckleshoot	WA	46,137	11

Concentrated Solar Power

The total technical potential on tribal lands for electricity generation from utility-scale rural solar resource is about 6 billion MWh, or 5.3% of total U.S. generation potential. The top tribal lands in terms of potential generation are Navajo (3 billion MWh), Tohono O'odham (950 million MWh), and Hopi (300 million MWh). Developable potential of CSP is often limited to utility scale, and by transmission availability and access. A full list of technical potential by tribal land is listed in Appendix 2.

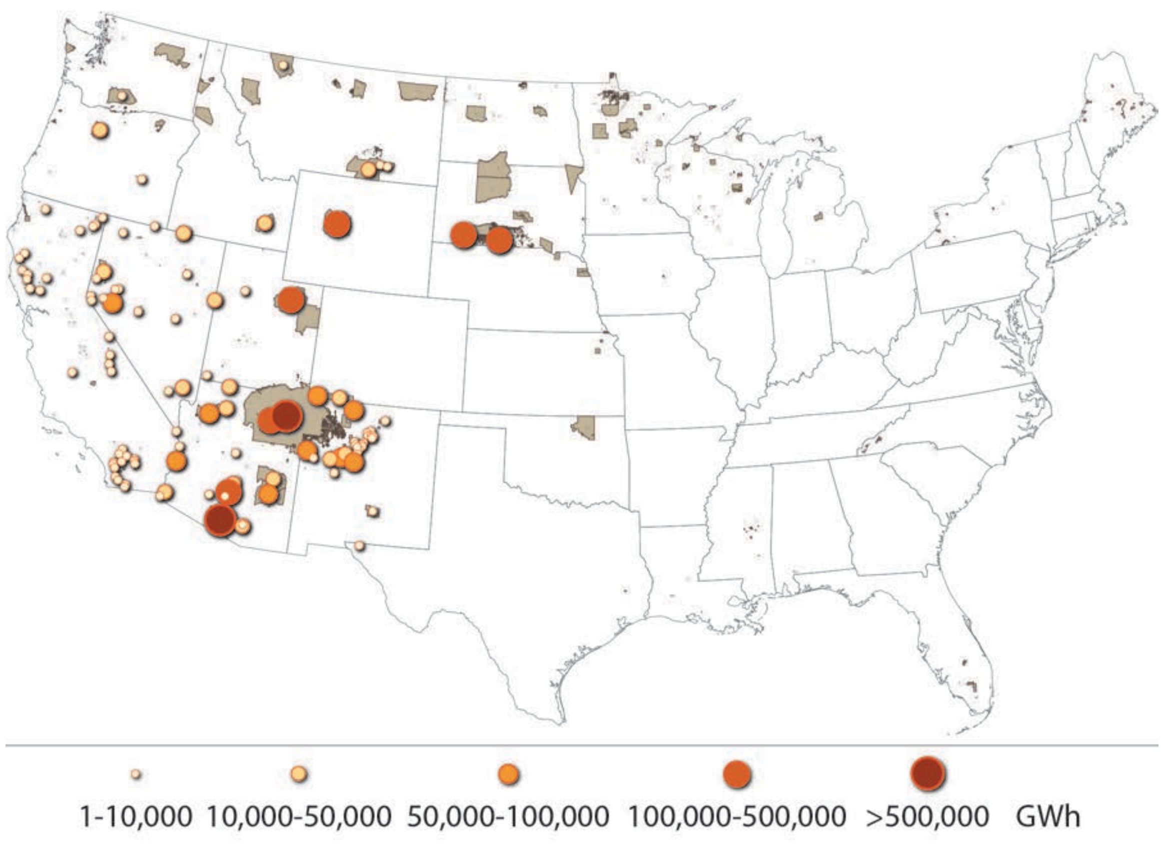

Figure 5. Tribal lands CSP generation potential

Table 4-6. Top 25 Tribal Lands by Technical Potential for CSP Generation

Tribal Land	State	Concentrating Solar Power Potential Annual Generation (MWh)	Concentrating Solar Power Potential Installed Capacity (MW)	Concentrating Solar Power Available Land (km^2)
Navajo	NM, UT, AZ, CO	2,872,729,112	830,414	25,950
Tohono O'odham	AZ	950,059,233	259,526	8,110
Hopi	AZ	332,743,795	95,030	2,970
Uintah and Ouray	UT	196,030,481	70,663	2,208
Pine Ridge	NE, SD	193,254,076	69,913	2,185
Wind River	WY	172,102,126	62,252	1,945
Rosebud	NE, SD	125,329,342	45,340	1,417
Gila River	AZ	123,184,942	35,754	1,117
Laguna Pueblo	NM	91,734,396	26,629	832
Colorado River	AZ, CA	87,227,378	24,292	759
San Carlos	AZ	87,046,169	24,426	763
Hualapai	AZ	68,215,389	18,755	586
Zuni Pueblo	NM, AZ	60,942,972	17,691	553
Jicarilla Apache	NM, CO	59,723,631	17,337	542
Walker River	NV	57,127,439	16,583	518
Isleta Pueblo	NM	54,658,370	15,867	496
Ute Mountain	NM, UT, CO	53,851,937	15,633	489
Acoma Pueblo	NM	47,628,883	13,826	432
Duck Valley	NV,ID	41,129,330	14,879	465
Southern Ute	NM, CO	40,693,628	11,813	369
Fort Hall	ID	36,419,526	13,175	412
White Mountain	AZ	30,465,149	8,844	276
Pyramid Lake	NV	29,464,482	9,905	310
Crow	WY, MT	28,153,272	10,185	318
Moapa Band River	NV	24,779,403	6,672	208

Solar PV: Urban Utility Scale

The total technical potential on tribal lands for generation from utility-scale solar resources on urban land is about 15 million MWh, or about 0.7% of the total U.S. technical potential. The top four tribal lands in terms of potential generation are Navajo (2 million MWh), Zuni Pueblo (1 million MWh), and San Juan Pueblo (1 million MWh). A full list of technical potential by tribal land is listed in Appendix 2.

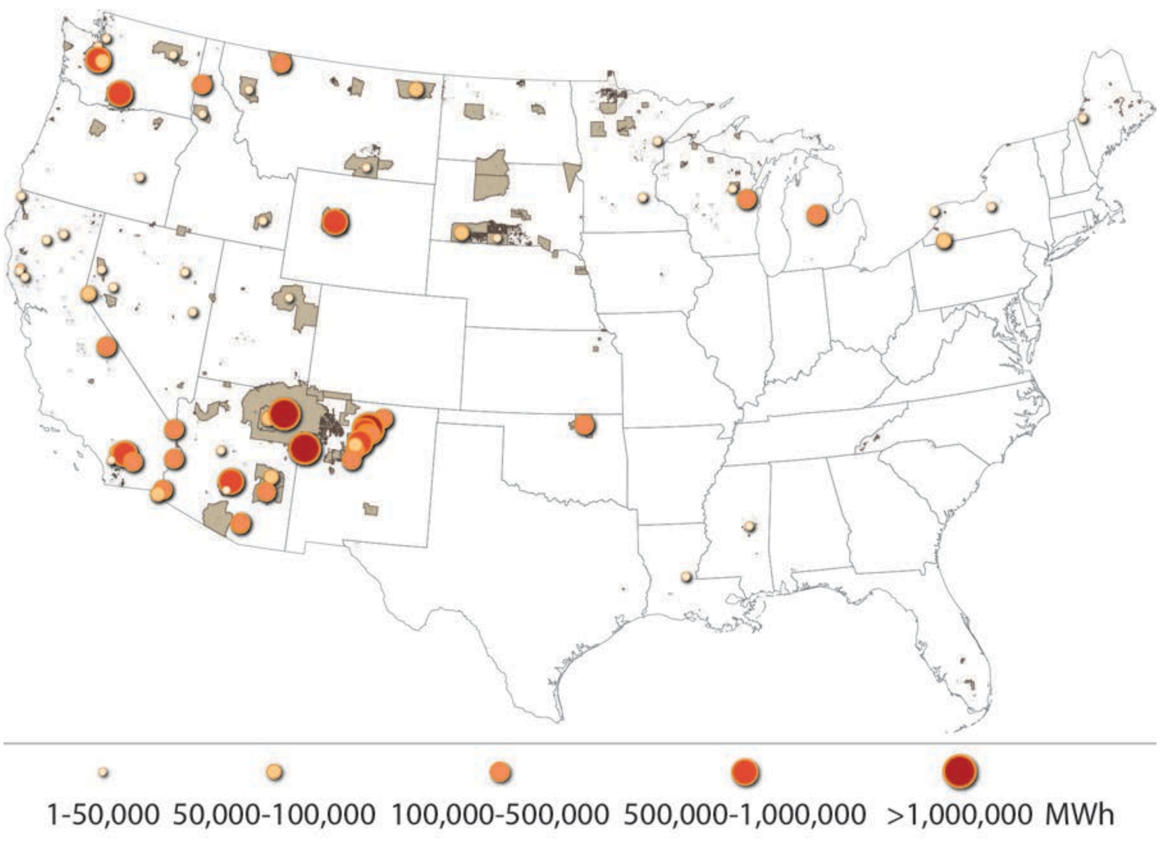

Figure 6. Tribal lands PV utility-scale urban generation potential

Table 4-7. Top 25 Tribal Lands by Technical Potential for Urban Utility-Scale PV Generation

Tribal Land	State	Urban Utility PV Power Potential Annual Generation (MWh)	Urban Utility PV Potential Installed Capacity (MW)	Urban Utility PV Available Land (km^2)
Navajo	NM, UT, AZ, CO	2,925,921	1,269	26
Zuni Pueblo	NM, AZ	1,176,908	511	11
San Juan Pueblo	NM	1,104,495	480	10
Santa Clara Pueblo	NM	1,017,361	442	9
Yakama	WA	985,616	565	12
Salt River	AZ	932,717	405	8
Agua Caliente	CA	798,375	362	8
Puyallup	WA	700,760	402	8
Wind River	WY	691,383	345	7
Santo Domingo Pueblo	NM	661,364	287	6
Osage	OK	562,649	288	6
Pojoaque Pueblo	NM	431,394	187	4
San Xavier (TON)	AZ	415,559	180	4
Taos Pueblo	NM	399,066	173	4
Oneida (West)	WI	372,008	237	5
Fort Mojave	NV, AZ, CA	340,340	150	3
Sandia Pueblo	NM	320,984	139	3
Torres-Martinez	CA	319,770	145	3
San Carlos	AZ	293,541	127	3
Isleta Pueblo	NM	263,889	115	2
Nambe Pueblo	NM	259,015	112	2
San Ildefonso Pueblo	NM	229,473	100	2
Coeur d'Alene	WA, ID	188,412	98	2
White Mountain	AZ	154,092	67	1
Blackfeet	MT	154,001	83	2

Solar PV: Rural Utility Scale

The total technical potential on tribal lands for electricity generation from utility-scale rural solar resource is about 9 billion MWh, or 3.3% of total U.S. generation potential. The top tribal lands in terms of potential generation are Navajo (2 billion MWh), Tohono O'odham (900 million MWh), and Fort Peck (450 million MWh). Developable potential of utility-scale solar is often limited by transmission availability and access. A full list of technical potential by tribal land is listed in Appendix 2.

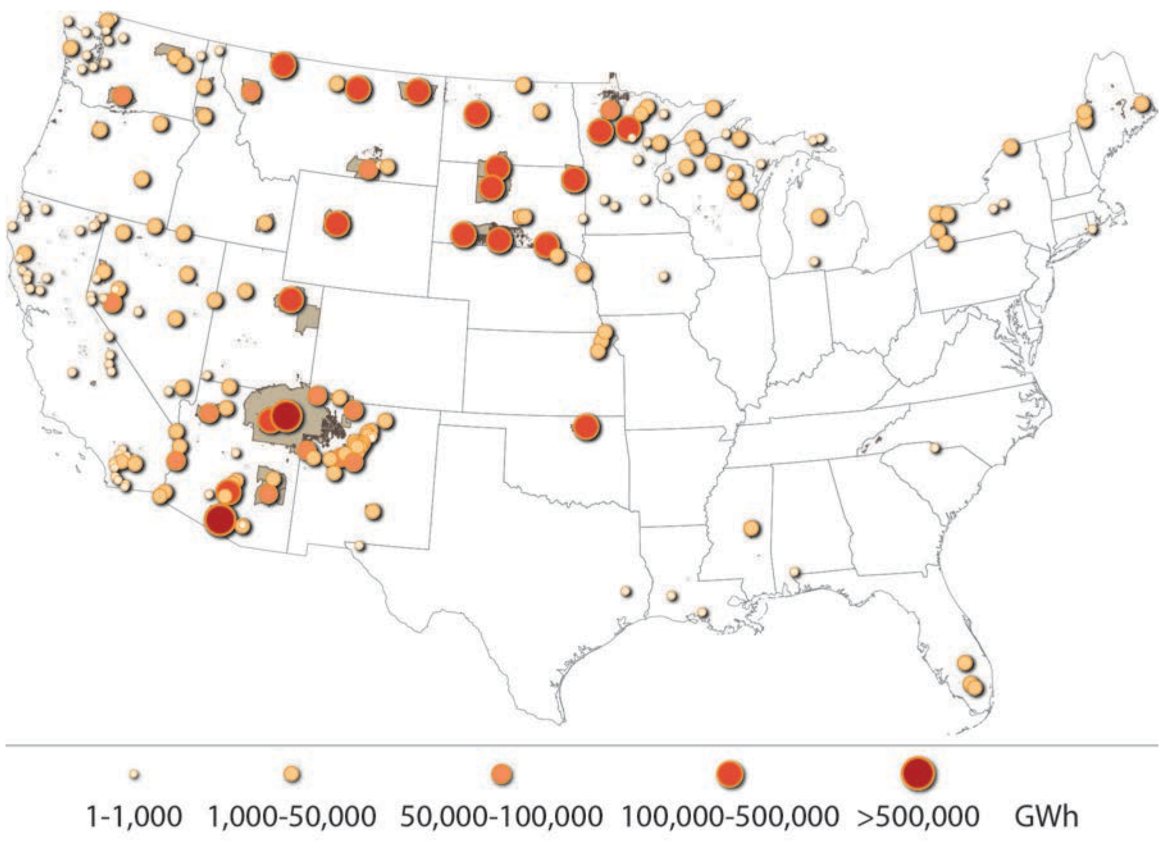

Figure 7. Tribal lands PV utility-scale rural generation potential

Table 4-8. Top 25 Tribal Lands by Technical Potential for Rural Utility-Scale PV Generation

Tribal Land	State	Rural Utility PV Power Potential Annual Generation (MWh)	Rural Utility PV Potential Installed Capacity (MW)	Rural Utility PV Available Land (km^2)
Navajo	NM, UT, AZ, CO	2,494,474,583	1,087,316	22,652
Hopi	AZ	2,295,637,379	998,053	20,793
Tohono O'odham	AZ	986,595,977	427,892	8,914
Standing Rock	SD, ND	932,953,632	503,395	10,487
Fort Peck	MT	609,883,158	327,966	6,833
Pine Ridge	NE, SD	450,036,180	240,320	5,007
Uintah and Ouray	UT	442,003,250	203,766	4,245
Osage	OK	325,020,763	166,400	3,467
Cheyenne River	SD	323,595,921	172,803	3,600
Wind River	WY	318,333,071	158,647	3,305
Blackfeet	MT	299,959,630	161,304	3,361
Rosebud	NE, SD	284,184,572	151,746	3,161
Lake Traverse (Sisseton)	SD, MN, ND	266,608,010	142,810	2,975
Zuni Pueblo	NM, AZ	196,586,404	85,349	1,778
San Carlos	AZ	187,916,024	81,500	1,698
Crow	WY, MT	183,354,288	98,599	2,054
White Earth	MN	180,721,292	109,009	2,271
Laguna Pueblo	NM	172,651,833	74,984	1,562
Fort Berthold	ND	168,674,984	95,006	1,979
Fort Belknap	MT	168,388,007	90,551	1,886
Jicarilla Apache	NM, CO	150,130,043	65,203	1,358
Hualapai	AZ	134,901,150	58,507	1,219
Leech Lake	MN	129,919,796	78,366	1,633
Gila River	AZ	129,768,914	56,282	1,173
Yankton	NE, SD	121,296,780	64,759	1,349

Wind

The total technical potential on tribal lands for electricity generation from wind resources is about 1.1 billion MWh, or about 3.4% of the total U.S. technical potential. The top four tribal lands in terms of potential generation are Cheyenne River (183 million MWh), Standing Rock (145 million MWh), Fort Peck (122 million MWh), and Pine Ridge (110 million MWh). Developable potential of utility-scale wind, particularly in the Midwest where the resource is strongest but typically far from energy intense population centers, is often limited by transmission availability and access. A full list of technical potential by tribal land is listed in Appendix 2.

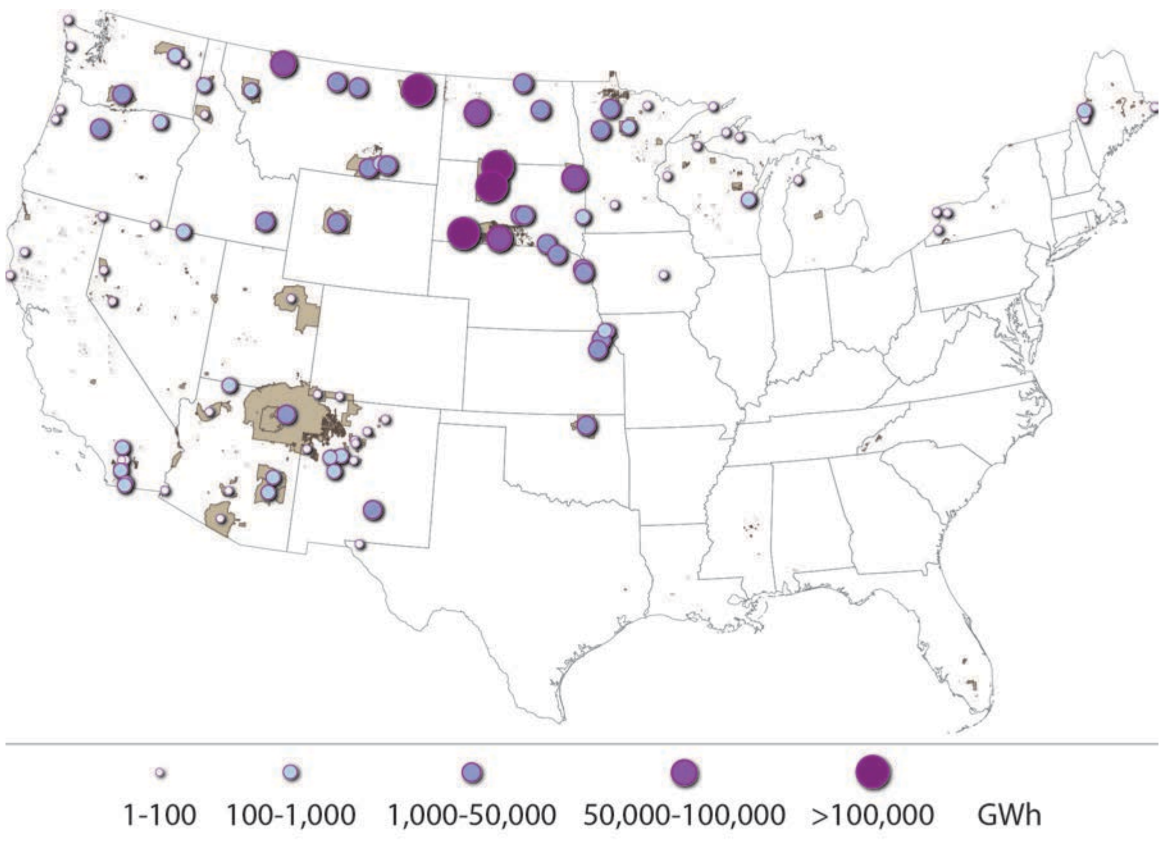

Figure 8. Tribal lands wind generation potential

Table 4-9. Top 25 Tribal Lands by Technical Potential for Wind Electricity Generation

Tribal Land	State	Wind Potential Annual Generation at 80 m and GCF>= 30% (MWh)	Wind Potential Installed Capacity at 80 m and GCF>= 30% (MW)	Wind Available Land at 80 m and GCF>= 30% (km²)
Cheyenne River	SD	188,088,492	57,806	11,561
Standing Rock	SD, ND	149,093,091	45,972	9,194
Fort Peck	MT	126,258,676	41,331	8,266
Pine Ridge	NE, SD	113,398,124	38,028	7,606
Rosebud	NE, SD	87,002,780	25,833	5,167
Blackfeet	MT	69,911,790	24,476	4,895
Lake Traverse (Sisseton)	SD, MN, ND	60,824,322	17,736	3,547
Fort Berthold	ND	51,781,459	16,409	3,282
Osage	OK	43,853,495	16,357	3,271
Crow	WY, MT	43,407,456	16,497	3,299
Fort Belknap	MT	32,739,605	11,725	2,345
Yankton	NE, SD	21,573,834	6,732	1,346
White Earth	MN	19,367,345	7,400	1,480
Crow Creek	SD	17,699,282	5,722	1,144
Lower Brule	SD	14,521,816	4,509	902
Devils Lake Sioux	ND	14,300,155	4,533	907
Omaha	IA, NE	12,508,456	3,919	784
Wind River	WY	12,306,226	4,345	869
Northern Cheyenne	MT	9,371,963	3,522	704
Winnebago	IA, NE	6,601,533	2,094	419
Santee	NE	6,489,284	2,118	424
Mescalero Apache	NM	5,566,143	2,240	448
Fort Hall	ID	5,031,295	2,026	405
Potawatomi Prairie Band	KS	4,562,289	1,548	310
Yakama	WA	3,720,634	1,383	277

5 Conclusion

This report provides a summary of the technical potential for capacity and generation from a variety of renewable resources on tribal lands. It is intended to provide information to Tribes and researchers as to the opportunity for development on tribal lands. Table A2-1 summarizes the estimated technical generation and capacity potential on tribal lands for each renewable electricity technology examined in this report. As estimates of technical, rather than economic or market potential, these values do not consider:

- Allocation of available land among technologies (available land is generally assumed to be available to support development of more than one technology, and each set of exclusions was applied independently)
- Availability of existing or planned transmission infrastructure that is necessary to tie generation into the electricity grid
- The dependability of consistent electricity generation, at a time coincident to when electricity is used
- The cost associated with developing power at any location
- Presence of local, state, regional, or national policies, either existing or potential, that could encourage renewable development
- The location or magnitude of current and potential areas of electricity need.

Overall, the analysis shows that the technical potential on tribal lands is about 6% of the total national technical potential. This is disproportionately larger than the 2% tribal lands in the United States, indicating an increased potential density for renewable energy development on tribal lands. Next steps for understanding the developable potential of renewable energy on tribal lands include assessing tribal interests in development (e.g., scale of project, purpose of project, cultural sensitivity avoidance); understanding the energy environment in which the project would function as a way of assessing potential project viability and economics; and working with the local utility and regulatory authorities to understand renewable energy needs.

Updates to these technical potentials are possible on an ongoing basis as resource, system, exclusions, and domain knowledge change and data sets improve in quality and resolution.

6 References

Doris, E.; Taylor, R. (2009). *2008 Weatherization and Intergovernmental Program Report.* TP-6A2-43614; DOE/GO-102009-2859. Golden, CO: National Renewable Energy Laboratory. Accessed Aug. 15, 2012: http://www.nrel.gov/docs/fy09osti/43614.pdf.

Lopez, A.; Roberts, B.; Heimiller, D.; Blair, N.; Porro, G. (2012). *2012 U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis.* NREL TP-6A20-51946. Accessed August 15, 2012: http://www.nrel.gov/docs/fy12osti/51946.pdf.

Porro, G.; Heimiller, D. (2006). *Report to Congress on Renewable Energy Resource Assessment Information for the United States - EPACT 201 Report.* NREL TP-6A20-50168; DOE/GO-102010-3206. Golden, CO: National Renewable Energy Laboratory.

Appendix 1. Exclusions and Constraints, Capacity Factors, and Power Densities

Table A-1. Exclusions and Constraints for Urban Utility-Scale Photovoltaics

Slope Exclusion	> 5%	
Contiguous Area Exclusion	< 0.018 km^2	
Land Type(s) Exclusion	Within Urban Boundaries	ESRI (2004)
	Landmarks	ESRI (2007a)
	Parks	ESRI (2007b)
	MRLC–Water	MRLC (n.d.)
	MRLC–Wetlands	MRLC (n.d.)
	MRLC–Forests	MRLC (n.d.)
	MRLC–Impervious Surface >= 1%	MRLC (n.d.)

Table A-2. Capacity Factors for Utility-Scale Photovoltaics[a]

State	Capacity Factor	State	Capacity Factor	State	Capacity Factor
Alabama	0.200	Maine	0.191	Oklahoma	0.223
Alaska	0.105	Maryland	0.179	Oregon	0.227
Arizona	0.263	Massachusetts	0.182	Pennsylvania	0.177
Arkansas	0.207	Michigan	0.173	Rhode Island	0.176
California	0.252	Minnesota	0.189	South Carolina	0.202
Colorado	0.259	Mississippi	0.197	South Dakota	0.214
Connecticut	0.182	Missouri	0.193	Tennessee	0.201
Delaware	0.186	Montana	0.212	Texas	0.218
Florida	0.209	Nebraska	0.217	Utah	0.248
Georgia	0.203	Nevada	0.263	Vermont	0.176
Hawaii	0.210	New Hampshire	0.184	Virginia	0.200
Idaho	0.220	New Jersey	0.200	Washington	0.199
Illinois	0.186	New Mexico	0.263	West Virginia	0.172
Indiana	0.184	New York	0.184	Wisconsin	0.180
Iowa	0.199	North Carolina	0.206	Wyoming	0.229
Kansas	0.238	North Dakota	0.203		
Kentucky	0.186	Ohio	0.173		
Louisiana	0.196				

[a] System Advisor Model (SAM)

Table A-3. Exclusions and Constraints for Rural Utility-Scale Photovoltaics and Concentrating Solar Power

Slope Exclusion	> 5%	
Contiguous Area Exclusion	< 1 km^2	
Land Type(s) Exclusion	Urban Areas	ESRI (2004)
	MRLC–Water	MRLC (n.d.)
	MRLC–Wetlands	MRLC (n.d.)
	BLM ACEC Lands (Areas of Critical Environmental Concern) (BLM 2009)	BLM (2009)
	Forest Service IRA (Inventoried Roadless Area) (USFS 2003)	USFS (2003)
	National Park Service Lands	USGS (2005)
	Fish & Wildlife Lands	USGS (2005)
	Federal Parks	USGS (2005)
	Federal Wilderness	USGS (2005)
	Federal Wilderness Study Area	USGS (2005)
	Federal National Monument	USGS (2005)
	Federal National Battlefield	USGS (2005)
	Federal Recreation Area	USGS (2005)
	Federal National Conservation Area	USGS (2005)
	Federal Wildlife Refuge	USGS (2005)
	Federal Wildlife Area	USGS (2005)
	Federal Wild and Scenic Area	USGS (2005)

Table A-4. Capacity Factors for Concentrating Solar Power[a]

Class	Kwh/m^2/day	Capacity Factor
1	5-6.25	0.315
2	6.25-7.25	0.393
3	7.25-7.5	0.428
4	7.5-7.75	0.434
5	> 7.75	0.448

[a] System Advisor Model (SAM)

Table A-5. Exclusions and Constraints for Onshore Wind Power

Slope Exclusion	> 20%	
Distance Exclusion	< 3 km Distance to Excluded Area (does not apply to water)	
Land Type(s) Exclusion	50% Forest Service Lands (includes National Grasslands, excludes ridge crests)	USGS (2005)
	50% Department of Defense Lands (excludes ridge crest)	USGS (2005)
	50% GAP Land Stewardship Class 2–Forest	CBI (2004)
	50% Exclusion of Non-Ridge Crest Forest (noncumulative over Forest Service land)	USGS (2005)
	Airports	ESRI (2003)
	Urban Areas	ESRI (2004)
	LULC–Wetlands	USGS (1993)
	LULC–Water	USGS (1993)
	Forest Service IRA (Inventoried Roadless Areas)	USFS (2003)
	National Park Service Lands	USGS (2005)
	Fish and Wildlife Lands	USGS (2005)
	Federal Parks	USGS (2005)
	Federal Wilderness	USGS (2005)
	Federal Wilderness Study Area	USGS (2005)
	Federal National Monument	USGS (2005)
	Federal National Battlefield	USGS (2005)
	Federal Recreation Area	USGS (2005)
	Federal National Conservation Area	USGS (2005)
	Federal Wildlife Refuge	USGS (2005)
	Federal Wildlife Area	USGS (2005)
	Federal Wild and Scenic Area	USGS (2005)
	GAP Land Stewardship Class 2–State and Private Lands Equivalent to Federal Exclusions	CBI (2004)

Table A-6. Capacity Factor for Offshore Wind Power[a]

Depth	Class	Watts/m²	Capacity Factor
Shallow			
0–30 meters	3	300-400	0.36
0–30 meters	4	400-500	0.39
0–30 meters	5	500-600	0.45
0–30 meters	6	600-800	0.479
0–30 meters	7	> 800	0.5
Deep			
> 30 meters	3	300-400	0.367
> 30 meters	4	400-500	0.394
> 30 meters	5	500-600	0.45
> 30 meters	6	600-800	0.479
> 30 meters	7	> 800	0.5

[a] Regional Energy Deployment System (ReEDS)

Table A-7. Conversion of Offshore Wind Speeds at 90 Meters to Power Classes[a]

Wind Speed (m/s)	Power Class
6.4-7.0	3
7.0-7.5	4
7.5-8.0	5
8.0-8.8	6
> 8.8	7

[a] Marc Schwartz, NREL wind analyst, personal communication

Table A-8. Exclusions and Constraints for Offshore Wind Power[a]

Distance Exclusion	< 50 nautical miles from shoreline
Land Type(s) Exclusion	
Federal Exclusions	National Marine Sanctuaries
	Marine Protected Areas Inventory–"NAL," "NIL," "NTL"
	Office of Habitat Conservation Habitat Protection Div. EFH–Shipping Routes, Sanctuary Protected Areas
	NOAA Jurisdictional Boundaries and Limits–Coastal
	National Wildlife Refuges–Pacific
	Navigational & Marine Infrastructure–Shipping Lanes, Drilling Platforms (Gulf), Pipelines (Gulf), Fairways (Gulf)
	NWIOOS–Towlane Agreement WSG 2007
	World Database on Protected Areas Annual Release 2009
	Global Dataset–Offshore Oil and Gas Pipelines/Drilling Platforms
Texas	Pipelines and Easements
	Audubon Sanctuaries
	Gulf Intercoastal Waterway/Ship Channels
	National Wildlife Refuges
	Shipping Safety Fairways
	State Coastal Preserves
	Dredged Material Placement Sites
	State Tracts with Resource Management Codes
North Carolina	Significant Natural Heritage Areas
	Sea Turtle Sanctuary
	Crane Spawning Sanctuary
Great Lakes	IM AOC EPA
	IM Ship Routes
Virginia	Near-shore Coastal Parks
	Threatened and Endangered Species Waters
	Crab Sanctuary
	Security Areas
	Striped Bass Sanctuary
	State Park and State Dedicated Natural Area Preserve (w/in 1 mile of shoreline)
Rhode Island	Habitat Restoration Area
	Hazardous Material Sites Designated by the U.S. EPA and RIDEM (w/in 0.5 miles of shoreline)
	CRMCWT08 (Type = 1 or 2)
South Carolina	Refuges
	OCRM Critical Area
New Hampshire	Conservation Focus Area
Florida	Ocean Dredged Material Disposal Sites
	Aquatic Preserve Boundaries
California	Cordell Banks Closed Areas

Massachusetts	Ferry Routes
Oregon	Oregon Islands National Wildlife Refuges USFWS 2004
	Oregon Marine Managed Areas
	Oregon Cables OFCC 2005
	Dredged Material Disposal Sites ACOE 2008
New Jersey	New Jersey Coastal Wind Turbine Siting Map–Exclusion Areas

[a] Exclusions were developed by Black and Veatch (2009).

Table A-9. Exclusions and Constraints for Enhanced Geothermal Systems[a]

Land Type(s) Exclusion	National Park Service Lands
	Fish and Wildlife Service Lands
	Federal Parks
	Federal Wilderness
	Federal National Monuments
	Federal National Battlefields
	Federal Restoration Areas
	Federal National Conservation Areas
	Federal Wildlife Refuge Areas
	Federal Wild and Scenic Areas

[a] United States Geological Survey (USGS) (2005)

Table A-10. Power Densities for Enhanced Geothermal Systems[a]

Temperature C	MW/km^2
150–200	0.59
200–250	0.76
250–300	0.86
300–350	0.97
> 350	1.19

[a] Augustine (2011)

Table A-11. Exclusions and Constraints for Enhanced Geothermal Systems[a]

Depth Constraints	Depth > 3 and < 10 km
Land Type(s) Exclusion	National Park Service Lands Fish and Wildlife Service Lands Federal Parks Federal Wilderness Federal National Monuments Federal National Battlefields Federal Restoration Areas Federal Conservation Areas Federal Wildlife Refuge Areas Federal Wild and Scenic Areas

[a] USGS (2005)

Appendix 2. Technical Potential by Tribal Lands for Renewable Resources

Table A2-1. Tribal Renewable Energy Potential—Hydrothermal, Hydropower, and Biopower

Tribal Land	State	Unidentified Hydrothermal Potential Annual Generation (MWh)	Unidentified Hydrothermal Potential Installed Capacity (MW)	Hydropower Generation Potential (MWh)	Hydropower Capacity Potential (MW)	Biopower from Solid Residues[a] (MWh)	Biopower from Solid Residues (MW)	Biopower from Gaseous Residues[b] (MWh)	Biopower from Gaseous Residues (MW)
Acoma Pueblo	NM	20,363	3	2,523	1	0	0	13	0
Agua Caliente	CA	475	0	3,783	1	6,322	1	268	0
Alabama and Coushatta	TX	-	-	-	-	3,493	0	3	0
Alamo (Navajo)	NM	8,452	1	1,152	0	2	0	1	0
Alturas Rancheria	CA	8	0	-	-	-	-	0	0
Augustine	CA	60	0	-	-	127	0	0	0
Bad River	WI	-	-	12,290	3	32,417	4	45	0
Barona Rancheria	CA	96	0	-	-	-	-	36	0
Bay Mills	MI, MI	-	-	168	0	22	0	1	0
Benton Paiute	CA	53	0	-	-	-	-	0	0
Berry Creek Rancheria	CA	0	0	-	-	5	0	0	0
Big Bend Rancheria	CA	11	0	-	-	21	0	0	0
Big Cypress	FL	-	-	-	-	15,013	2	17	0
Big Lagoon Rancheria	CA	-	-	-	-	5	0	0	0
Big Pine Rancheria	CA	83	0	-	-	-	-	0	0
Big Sandy Rancheria	CA	1	0	-	-	5	0	0	0
Big Valley Rancheria	CA	258	0	-	-	64	0	0	0
Bishop Rancheria	CA	521	0	-	-	448	0	0	0
Blackfeet	MT	60,031	8	445,893	102	87,202	11	98	0
Blue Lake Rancheria	CA	1	0	-	-	20	0	0	0
Bois Forte (Nett Lake)	MN	-	-	-	-	28,872	4	3	0
Bridgeport Colony	CA	18	0	-	-	-	-	0	0
Brighton	FL	-	-	-	-	18,809	2	24	0
Burns Paiute	OR	2,436	0	-	-	21	0	0	0
Cabazon	CA	604	0	112	0	124	0	44	0
Cahuilla	CA	511	0	241	0	67	0	7	0
Camp Verde	AZ	25	0	-	-	26	0	1	0
Campo	CA	760	0	307	0	-	-	3	0

Tribal Land	State	Unidentified Hydrothermal Potential Annual Generation (MWh)	Unidentified Hydrothermal Potential Installed Capacity (MW)	Hydropower Generation Potential (MWh)	Hydropower Capacity Potential (MW)	Biopower from Solid Residues[a] (MWh)	Biopower from Solid Residues (MW)	Biopower from Gaseous Residues[b] (MWh)	Biopower from Gaseous Residues (MW)
Capitan Grande	CA	165	0	1,624	0	-	-	16	0
Carson Colony	NV	66	0	-	-	58	0	0	0
Catawba	SC	-	-	-	-	645	0	4	0
Cattaraugus (Seneca)	NY	-	-	9,678	2	971	0	26	0
Cedarville Rancheria	CA	21	0	-	-	0	0	0	0
Chehalis	WA	10	0	1,545	0	3,205	0	2	0
Chemehuevi	CA	4,412	1	-	-	-	-	2	0
Cheyenne River	SD	-	-	47,065	11	35,581	5	68	0
Chicken Ranch Rancheria	CA	0	0	-	-	0	0	0	0
Chitimacha	LA	-	-	-	-	172	0	2	0
Cochiti Pueblo	NM	17,958	2	25,682	6	39	0	33	0
Cocopah	AZ, CA	1,368	0	-	-	1,161	0	25,403	3
Coeur d'Alene	WA,ID	24,563	3	18,416	4	264,737	34	84	0
Cold Springs Rancheria	CA	0	0	-	-	1	0	0	0
Colorado River	AZ, CA	41,401	5	106,505	24	17,814	2	34	0
Colusa (Cachil Dehe) Rancheria	CA	1	0	-	-	13	0	0	0
Colville	WA	70,390	9	247,936	57	59,616	8	89	0
Coos, Lower Umpqua, and Siuslaw	OR	0	0	-	-	5	0	0	0
Cortina Rancheria	CA	40	0	-	-	-	-	0	0
Coushatta	LA	-	-	-	-	73	0	0	0
Cow Creek	OR	0	0	-	-	-	-	0	0
Coyote Valley	CA	22	0	-	-	72	0	0	0
Crow	WY, MT	28,073	4	89,049	20	43,001	5	229	0
Crow Creek	SD	-	-	3,303	1	23,293	3	18	0
Crow/Northern Cheyenne Area	MT	417	0	-	-	17	0	0	0
Cuyapaipe	CA	227	0	-	-	-	-	1	0
Deer Creek	MN	-	-	-	-	1,800	0	1	0
Devils Lake Sioux	ND	-	-	-	-	46,079	6	32	0
Dresslerville Colony	NV	15	0	-	-	14	0	0	0
Dry Creek Rancheria	CA	192	0	-	-	6	0	0	0
Duck Valley	NV, ID	164,004	21	14,913	3	-	-	2	0
Duckwater	NV	915	0	-	-	-	-	0	0
Eastern Cherokee	NC	-	-	13,299	3	3,223	0	25	0
Elk Valley Rancheria	CA	1	0	-	-	29	0	0	0
Ely Colony	NV	57	0	-	-	60	0	0	0
Enterprise Rancheria	CA	0	0	-	-	6	0	0	0

Tribal Land	State	Unidentified Hydrothermal Potential Annual Generation (MWh)	Unidentified Hydrothermal Potential Installed Capacity (MW)	Hydropower Generation Potential (MWh)	Hydropower Capacity Potential (MW)	Biopower from Solid Residues[a] (MWh)	Biopower from Solid Residues (MW)	Biopower from Gaseous Residues[b] (MWh)	Biopower from Gaseous Residues (MW)
Fallon	NV	6,611	1	-	-	-	-	1	0
Fallon Colony	NV	75	0	-	-	19	0	0	0
Flandreau	SD	-	-	621	0	1,565	0	0	0
Flathead	MT	151,999	19	816,341	186	123,572	16	262	0
Fond du Lac	MN	-	-	8,042	2	41,847	5	86	0
Fort Belknap	MT	7,786	1	5,108	1	16,216	2	14	0
Fort Berthold	ND	-	-	3,819	1	109,151	14	43	0
Fort Bidwell	CA	3,080	0	1,265	0	47	0	0	0
Fort Hall	ID	179,275	23	70,593	16	101,896	13	210	0
Fort Independence	CA	50	0	-	-	-	-	0	0
Fort McDermitt	NV, OR	18,956	2	2,347	1	3	0	0	0
Fort Mojave	NV, AZ, CA	4,992	1	3,050	1	565	0	50	0
Fort Peck	MT	120,159	15	57,645	13	159,234	20	71	0
Fort Yuma (Quechan)	AZ, CA	9,903	1	12,331	3	2,518	0	7	0
Gila Bend (TON)	AZ	112	0	-	-	1	0	0	0
Gila River	AZ	27,789	4	47,987	11	26,922	3	459	0
Goshute	NV, UT	44,152	6	5,833	1	75	0	1	0
Grand Portage	MN	-	-	10,877	2	3,174	0	3	0
Grand Ronde	OR	23	0	6,123	1	20,641	3	3	0
Grand Traverse	MI	-	-	-	-	2	0	0	0
Greenville Rancheria	CA	13	0	-	-	29	0	0	0
Grindstone Creek Rancheria	CA	1	0	-	-	-	-	0	0
Hannahville Community	MI	-	-	-	-	763	0	1	0
Havasupai	AZ	9,880	1	5,692	1	153	0	4	0
Ho-Chunk	WI	-	-	1,364	0	68,939	9	7	0
Hoh	WA	-	-	-	-	34	0	0	0
Hollywood (Seminole)	FL	-	-	-	-	406	0	29	0
Hoopa Valley	CA	623	0	38,550	9	55,748	7	10	0
Hopi	AZ	42,330	5	1,860	0	745	0	62	0
Hopland Rancheria	CA	31	0	-	-	10	0	0	0
Hualapai	AZ	210,076	27	897	0	580	0	16	0
Huron Potawatomi	MI	-	-	-	-	51	0	0	0
Inaja-Cosmit	CA	48	0	895	0	-	-	0	0
Indian Township (Passamaquoddy)	ME	-	-	157	0	3,797	0	4	0
Iowa	KS, NE, MO	-	-	237	0	7,368	1	2	0

Tribal Land	State	Unidentified Hydrothermal Potential Annual Generation (MWh)	Unidentified Hydrothermal Potential Installed Capacity (MW)	Hydropower Generation Potential (MWh)	Hydropower Capacity Potential (MW)	Biopower from Solid Residues[a] (MWh)	Biopower from Solid Residues (MW)	Biopower from Gaseous Residues[b] (MWh)	Biopower from Gaseous Residues (MW)
Isabella (Sag Chip)	MI	-	-	5,177	1	41,506	5	320	0
Isleta Pueblo	NM	44,203	6	8,483	2	561	0	169	0
Jackson Rancheria	CA	1	0	418	0	29	0	0	0
Jamestown S'Klallam	WA	0	0	-	-	2	0	0	0
Jamul Village	CA	0	0	-	-	-	-	0	0
Jemez Pueblo	NM	32,709	4	3,944	1	25	0	14	0
Jicarilla Apache	NM, CO	143,397	18	15,647	4	10,155	1	16	0
Kaibab	AZ	17,715	2	452	0	14	0	4	0
Kalispel	WA	177	0	-	-	923	0	1	0
Karuk	CA	1	0	-	-	88	0	0	0
Kickapoo	KS	-	-	1,109	0	10,874	1	5	0
Kootenai	ID	1	0	-	-	0	0	0	0
La Jolla	CA	-	-	30,993	7	-	-	9	0
La Posta	CA	376	0	516	0	-	-	1	0
Lac Courte Oreilles	WI	205	0	616	0	27,629	4	16	0
Lac du Flambeau	WI	-	-	-	-	12,766	2	27	0
Lac Vieux Desert	MI	-	-	-	-	-	-	0	0
Laguna Pueblo	NM	-	-	8,823	2	43	0	38	0
Lake Traverse (Sisseton)	SD, MN, ND	88,772	11	229	0	300,466	38	97	0
L'Anse	MI	-	-	6,201	1	7,898	1	22	0
Las Vegas Colony	NV	509	0	-	-	10	0	2	0
Laytonville Rancheria	CA	15	0	-	-	54	0	0	0
Leech Lake	MN	-	-	1,792	0	158,657	20	126	0
Likely Rancheria	CA	2	0	-	-	0	0	0	0
Lone Pine Rancheria	CA	84	0	-	-	-	-	888	0
Lookout Rancheria	CA	29	0	-	-	-	-	0	0
Los Coyotes	CA	1,111	0	362	0	-	-	2	0
Lower Brule	SD	-	-	225	0	12,104	2	11	0
Lower Elwha	WA	-	-	-	-	94	0	0	0
Lower Sioux Community	MN	-	-	-	-	874	0	1	0
Lummi	WA	12	0	1,263	0	1,210	0	50	0
Makah	WA	45	0	5,908	1	11,043	1	3	0
Manchester (Point Arena) Rancheria	CA	12	0	-	-	104	0	0	0
Manzanita	CA	204	0	164	0	-	-	1	0
Maricopa (Ak-Chin)	AZ	2,313	0	313	0	11,100	1	9	0
Mashantucket Pequot	CT	-	-	-	-	5	0	5	0

Tribal Land	State	Unidentified Hydrothermal Potential Annual Generation (MWh)	Unidentified Hydrothermal Potential Installed Capacity (MW)	Hydropower Generation Potential (MWh)	Hydropower Capacity Potential (MW)	Biopower from Solid Residues[a] (MWh)	Biopower from Solid Residues (MW)	Biopower from Gaseous Residues[b] (MWh)	Biopower from Gaseous Residues (MW)
Menominee	WI	-	-	11,198	3	246,145	31	42	0
Mesa Grande	CA	587	0	593	0	-	-	1	0
Mescalero Apache	NM	41,007	5	7,696	2	10,073	1	27	0
Miccosukee	FL	-	-	-	-	17	0	0	0
Middletown Rancheria	CA	523	0	-	-	-	-	0	0
Mille Lacs	MN	-	-	-	-	117	0	1	0
Minnesota (Chippewa) Homestead Trust Lands	MN	-	-	-	-	88	0	0	0
Mississippi Choctaw	MS	-	-	-	-	23,696	3	12	0
Moapa Band River	NV	15,138	2	784	0	-	-	4	0
Montgomery Creek Rancheria	CA	14	0	-	-	45	0	0	0
Morongo	CA	1,515	0	4,523	1	183	0	77	0
Muckleshoot	WA	9	0	46,137	11	1,911	0	56	0
Nambe Pueblo	NM	7,461	1	2,720	1	327	0	13	0
Narragansett	RI	-	-	-	-	12	0	6	0
Navajo	NM, UT, AZ, CO	597,545	76	369,000	84	103,018	13	1,755	0
Nez Perce	ID	51,827	7	1,445,260	330	336,781	43	104	0
Nisqually	WA	12	0	57,594	13	3,049	0	23	0
Nooksack	WA	68	0	2,473	1	342	0	4	0
North Fork Rancheria	CA	0	0	-	-	-	-	0	0
Northern Cheyenne	MT	17,254	2	10,969	3	16,660	2	35	0
Northwestern Shoshoni	UT	69	0	358	0	-	-	0	0
Oil Springs	NY	-	-	-	-	31	0	0	0
Omaha	IA, NE	-	-	61,961	14	143,838	18	44	0
Oneida (East)	NY	-	-	-	-	2	0	0	0
Oneida (West)	WI	-	-	723	0	33,087	4	232	0
Onondaga	NY	-	-	2,880	1	727	0	17	0
Ontonagon	MI	-	-	-	-	200	0	0	0
Osage	OK	-	-	33,957	8	13,679	2	659	0
Ozette	WA	-	-	-	-	121	0	0	0
Paiute of Utah	UT	14,736	2	2,268	1	6	0	24	0
Pala	CA	789	0	2,933	1	-	-	12	0
Pascua Yaqui	AZ	135	0	-	-	415	0	10	0
Passamaquoddy Homestead Trust Lands	ME	-	-	5,322	1	12,789	2	0	0

Tribal Land	State	Unidentified Hydrothermal Potential Annual Generation (MWh)	Unidentified Hydrothermal Potential Installed Capacity (MW)	Hydropower Generation Potential (MWh)	Hydropower Capacity Potential (MW)	Biopower from Solid Residues[a] (MWh)	Biopower from Solid Residues (MW)	Biopower from Gaseous Residues[b] (MWh)	Biopower from Gaseous Residues (MW)
Pauma	CA	220	0	-	-	-	-	2	0
Payson (Yavapai-Apache) Community	AZ	5	0	-	-	-	-	0	0
Pechanga	CA	357	0	-	-	219	0	32	0
Penobscot	ME	-	-	189,260	43	12,513	2	13	0
Picayune Rancheria	CA	0	0	-	-	-	-	0	0
Picuris Pueblo	NM	11,905	2	8,657	2	27	0	3	0
Pine Ridge	NE, SD	-	-	29,895	7	13,596	2	124	0
Pinoleville Rancheria	CA	36	0	-	-	71	0	0	0
Pit River Tribe of California	CA	312	0	2,098	0	168	0	0	0
Pleasant Point (Passamaquoddy)	ME	-	-	-	-	28	0	1	0
Poarch Creek	AL	-	-	-	-	27	0	0	0
Pojoaque Pueblo	NM	5,128	1	567	0	571	0	7	0
Poospatuck	NY	-	-	-	-	27	0	2	0
Port Gamble	WA	5	0	-	-	111	0	4	0
Port Madison	WA	20	0	-	-	2,192	0	61,835	8
Potawatomi Forest County	WI	-	-	-	-	2,377	0	2	0
Potawatomi Prairie Band	KS	-	-	772	0	11,095	1	19	0
Prairie Island Community	MN	-	-	-	-	65	0	0	0
Puyallup	WA	46	0	9,170	2	15,640	2	427	0
Pyramid Lake	NV	324,409	41	31,167	7	222	0	8	0
Quartz Valley Rancheria	CA	1	0	-	-	76	0	0	0
Quileute	WA	-	-	-	-	408	0	0	0
Quinault	WA	406	0	339,978	78	161,549	20	12	0
Ramah Navajo Community	NM	1,875	0	-	-	0	0	1	0
Ramona	CA	26	0	-	-	-	-	0	0
Red Cliff	WI	-	-	-	-	2,145	0	3	0
Red Lake	MN	-	-	117	0	124,764	16	54	0
Redding Rancheria	CA	0	0	-	-	18	0	0	0
Redwood Valley Rancheria	CA	29	0	-	-	69	0	0	0
Reno-Sparks Colony	NV	1,991	0	-	-	18	0	8	0
Resighini Rancheria	CA	3	0	-	-	14	0	0	0
Rincon	CA	101	0	968	0	-	-	7	0
Roaring Creek Rancheria	CA	22	0	-	-	39	0	0	0
Robinson Rancheria	CA	54	0	-	-	-	-	0	0
Rocky Boy's	MT	3,044	0	2,858	1	18,430	2	9	0
Rohnerville Rancheria	CA	1	0	-	-	27	0	0	0

Tribal Land	State	Unidentified Hydrothermal Potential Annual Generation (MWh)	Unidentified Hydrothermal Potential Installed Capacity (MW)	Hydropower Generation Potential (MWh)	Hydropower Capacity Potential (MW)	Biopower from Solid Residues[a] (MWh)	Biopower from Solid Residues (MW)	Biopower from Gaseous Residues[b] (MWh)	Biopower from Gaseous Residues (MW)
Rosebud	NE, SD	-	-	31,800	7	20,291	3	85	0
Round Valley	CA	1,672	0	20,205	5	15,239	2	2	0
Rumsey Rancheria	CA	2	0	-	-	-	-	0	0
Sac and Fox (Iowa)	IA	-	-	3,564	1	2,952	0	2	0
Sac and Fox (KS-NE)	KS, NE	-	-	4,678	1	8,689	1	5	0
Salt River	AZ	3,589	0	17,910	4	3,495	0	59,395	8
San Carlos	AZ	179,374	23	49,442	11	12,211	2	76	0
San Felipe Pueblo	NM	13,693	2	9,678	2	17	0	19	0
San Felipe/Santa Ana joint area	NM	191	0	-	-	0	0	0	0
San Felipe/Santo Domingo joint area	NM	216	0	-	-	0	0	0	0
San Ildefonso Pueblo	NM	11,631	1	13,036	3	349	0	15	0
San Juan Pueblo	NM	10,803	1	12,465	3	1,859	0	48	0
San Manuel	CA	41	0	-	-	5	0	3	0
San Pasqual	CA	34	0	-	-	-	-	2	0
San Xavier (TON)	AZ	13,619	2	2,638	1	575	0	293	0
Sandia Pueblo	NM	4,499	1	1,770	0	596	0	53	0
Sandy Lake	MN	-	-	-	-	0	0	0	0
Santa Ana Pueblo	NM	17,965	2	7,128	2	133	0	37	0
Santa Clara Pueblo	NM	34,534	4	11,984	3	2,109	0	104	0
Santa Rosa	CA	1,390	0	108	0	-	-	1	0
Santa Rosa Rancheria	CA	1	0	-	-	18	0	0	0
Santa Ynez	CA	43	0	-	-	31	0	0	0
Santa Ysabel	CA	1,249	0	599	0	-	-	1	0
Santee	NE	-	-	4,184	1	27,871	4	10	0
Santo Domingo Pueblo	NM	20,388	3	10,871	2	718	0	40	0
Sauk-Suiattle	WA	2	0	-	-	11	0	0	0
Sault Ste. Marie	MI, MI	-	-	-	-	104	0	1	0
Seminole Homestead Trust Lands	FL	-	-	-	-	10	0	0	0
Seneca (Allegany)	PA, NY	-	-	-	-	4,979	1	17	0
Shakopee Community	MN	-	-	-	-	126	0	2	0
Sheep Ranch Rancheria	CA	0	0	-	-	0	0	0	0
Sherwood Valley Rancheria	CA	37	0	-	-	81	0	0	0
Shingle Springs Rancheria	CA	1	0	-	-	-	-	0	0
Shoalwater	WA	-	-	-	-	390	0	0	0
Siletz	OR	9	0	-	-	1,072	0	1	0
Skokomish	WA	12	0	15,169	3	6,301	1	6	0

Tribal Land	State	Unidentified Hydrothermal Potential Annual Generation (MWh)	Unidentified Hydrothermal Potential Installed Capacity (MW)	Hydropower Generation Potential (MWh)	Hydropower Capacity Potential (MW)	Biopower from Solid Residues[a] (MWh)	Biopower from Solid Residues (MW)	Biopower from Gaseous Residues[b] (MWh)	Biopower from Gaseous Residues (MW)
Skull Valley	UT	15,562	2	-	-	-	-	0	0
Smith River Rancheria	CA	0	0	-	-	8	0	0	0
Soboba	CA	263	0	854	0	165	0	64	0
Southern Ute	NM, CO	188,245	24	243,721	56	1,978	0	144	0
Spokane	WA	12,184	2	16,571	4	66,932	8	18	0
Squaxin Island	WA	4	0	-	-	1,159	0	2	0
St. Croix	WI	-	-	-	-	278	0	1	0
St. Regis Mohawk	NY	-	-	3,293	1	2,257	0	21	0
Standing Rock	SD, ND	-	-	18,638	4	24,045	3	64	0
Stewarts Point Rancheria	CA	16	0	-	-	5	0	0	0
Stillaguamish	WA	0	0	-	-	7	0	0	0
Stockbridge-Munsee	WI	-	-	-	-	74	0	1	0
Sulphur Bank (El-Em) Rancheria	CA	76	0	-	-	-	-	0	0
Summit Lake	NV	10,851	1	-	-	-	-	0	0
Susanville	CA	79	0	-	-	176	0	0	0
Swinomish	WA	39	0	3,080	1	1,769	0	22	0
Sycuan	CA	5	0	-	-	-	-	12	0
Table Bluff Rancheria	CA	-	-	-	-	5	0	0	0
Table Mountain Rancheria	CA	1	0	-	-	6	0	0	0
Taos Pueblo	NM	46,205	6	16,518	4	985	0	62	0
Te-Moak	NV	14,860	2	6,340	1	169	0	1	0
Tesuque Pueblo	NM	5,948	1	635	0	58	0	9	0
To'Hajiilee Chapter, Navajo Nation	NM	11,434	1	398	0	8	0	10	0
Tohono O'odham	AZ	510,243	65	-	-	7,512	1	296	0
Tonawanda	NY	-	-	779	0	156	0	5	0
Torres-Martinez	CA	10,284	1	152	0	1,160	0	10	0
Trinidad Rancheria	CA	-	-	-	-	42	0	0	0
Tulalip	WA	62	0	815	0	9,470	1	164	0
Tule River	CA	140	0	23,717	5	788	0	76	0
Tunica-Biloxi	LA	-	-	-	-	141	0	0	0
Tuolumne Rancheria	CA	1	0	926	0	83	0	1	0
Turtle Mountain	ND, MT	0	0	-	-	6,268	1	34	0
Tuscarora	NY	-	-	-	-	708	0	440,925	56
Twenty-Nine Palms	CA	18	0	-	-	-	-	0	0
Uintah and Ouray	UT	78,807	10	442,276	101	11,811	1	335	0

Tribal Land	State	Unidentified Hydrothermal Potential Annual Generation (MWh)	Unidentified Hydrothermal Potential Installed Capacity (MW)	Hydropower Generation Potential (MWh)	Hydropower Capacity Potential (MW)	Biopower from Solid Residues[a] (MWh)	Biopower from Solid Residues (MW)	Biopower from Gaseous Residues[b] (MWh)	Biopower from Gaseous Residues (MW)
Umatilla	OR	3,998	1	57,403	13	31,490	4	34	0
Upper Lake Rancheria	CA	119	0	-	-	-	-	0	0
Upper Sioux Community	MN	-	-	-	-	653	0	0	0
Upper Skagit	WA	1	0	-	-	22	0	0	0
Ute Mountain	NM, UT, CO	40,583	5	34,258	8	5,442	1	27	0
Vermillion Lake	MN	-	-	-	-	137	0	0	0
Viejas Rancheria	CA	15	0	-	-	-	-	3	0
Walker River	NV	246,481	31	16,585	4	-	-	14	0
Warm Springs	OR	405,953	51	130,737	30	35,935	5	31	0
Washoe	NV	687	0	10,030	2	121	0	3	0
White Earth	MN	-	-	3,357	1	138,785	18	115	0
White Mountain	AZ	119,240	15	115,435	26	14,148	2	182	0
Wind River	WY	47,999	6	350,640	80	6,349	1	183	0
Winnebago	IA, NE	-	-	48,821	11	76,709	10	22	0
Winnemucca Colony	NV	350	0	-	-	13	0	0	0
Woodfords Community	CA	89	0	-	-	-	-	0	0
XL Ranch	CA	8,312	1	2,726	1	117	0	1	0
Yakama	WA	155,549	20	669,640	153	274,750	35	329	0
Yankton	NE, SD	-	-	5,029	1	114,257	14	55	0
Yavapai	AZ	197	0	-	-	639	0	8	0
Yawapa Apache	AZ	1,658	0	14,108	3	190	0	74,323	9
Yerington	NV	268	0	-	-	9	0	0	0
Yomba	NV	1,941	0	172	0	-	-	0	0
Ysleta Del Sur Pueblo	TX	-	-	-	-	15	0	1	0
Yurok	CA	642	0	912	0	25,962	3	6	0
Zia Pueblo	NM	34,064	4	1,864	0	38	0	6	0
Zuni Pueblo	NM, AZ	44,632	6	7,926	2	3,457	0	67	0

[a] Solid residues are represented by forest, crop, primary mill, and urban wood residues. Generation estimated assuming 1.1 MWh/bone dry tonne of residue.

[b] Gaseous residues are represented by landfill and domestic wastewater residues. Generation estimated assuming 4.7 MWh/tonne of CH_4 produced by the residues.