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Technical Potential of Solar in Peru using the Renewable Energy Data Explorer

Renewable Energy (RE) Data Explorer is a publicly available web-based platform that allows users to visualize and analyze renewable energy potential in innovative ways using geospatial data.[1] As a part of the Leadership Compact managed by the U.S. Department of State and U.S. Agency for International Development (USAID), the National Renewable Energy Laboratory (NREL) worked in collaboration with the Peruvian Ministry of Energy and Mines (MINEM) to develop the Peru RE Data Explorer. NREL partnered with MINEM to gather relevant and geographically diverse weather, solar-radiation, wind-speed, and land-use information to populate the Peru RE Data Explorer[2]. Solar resource data were gathered from NREL's National Solar Radiation Database (NSRDB)[3] at a resolution of 4 km by 4 km grids. The tool also contains wind and weather resource data from the Global Wind Atlas[4]. All resource and land data are available for download by users. This is a first-of-its-kind tool for Peru, and it allows decision makers to assess renewable energy potential and set development targets to meet Peru's growing energy demand.

The Technical Potential tool (within RE Data Explorer) allows users to rapidly visualize the land area available to install renewable energy technologies by excluding undevelopable land according to user-defined assumptions. Along with this land area, the Technical Potential tool calculates the potential installed capacity and annual generation for technologies. Knowing the technical potential of technologies in a country allows policymakers to set upper-bound renewable energy targets and provides an informed view of where the best resources are located for potential development.

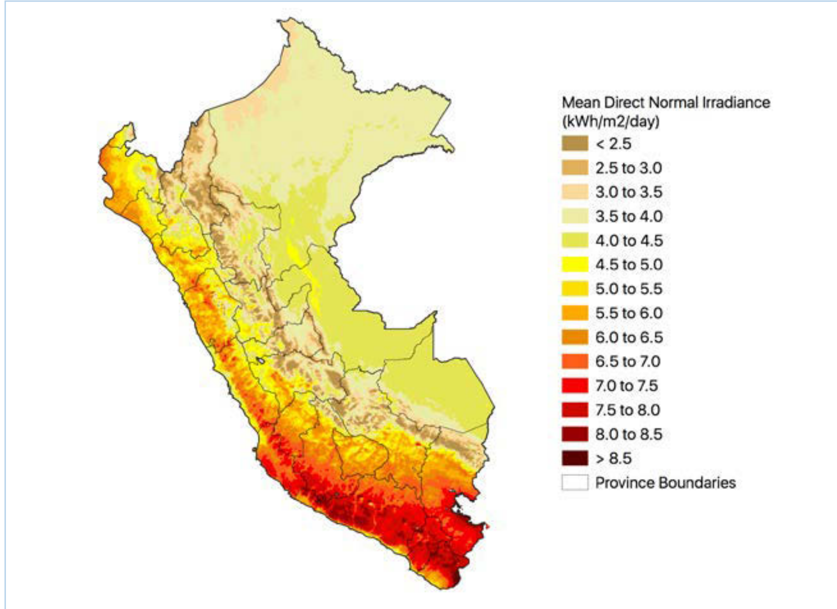

Figure 1. Results showing the overall solar resource in Peru, calculated in the RE Data Explorer.

In other countries, this tool has been used to support early-stage renewable energy target setting (with an upper-bound estimate of resource availability), policymaking (informing renewable portfolios standards, land-use policies, and other policies), investment (early-stage identification of favorable sites for on-the-ground resource measurement and validation), and power sector planning (key inputs to power sector modeling and supporting proactive planning approaches). For more information about specific country contexts, please visit *https://www.re-explorer.org/where-we-work.html.*

At the request of the Nationally Appropriate Mitigation Action (*NAMA Project*), which is sponsored by the United Nations Development Programme-Global Environmental Finance [UNDP-GEF] program and located within MINEM, this fact sheet details the methodology and results of calculating the technical potential of photovoltaic (PV) and concentrating solar power (CSP) technologies in Peru based on resource, land-use, and geographic constraints using the Peru RE Data Explorer tool.

[1]https://www.nrel.gov/docs/fy17osti/68180.pdf
[2]https://maps.nrel.gov/rede-peru/
[3]https://nsrdb.nrel.gov/
[4]https://globalwindatlas.info/

Technical Potential Description

"Technical potential analysis shows the achievable energy capacity and generation of a particular technology given resource potential, system performance, topographic limitations, environmental attributes, and land-use constraints"[5].

The RE Data Explorer technical potential tool first calculates the available land area after removing resource and geographical constraints (protected areas, urbanized areas, water bodies, terrain features, etc.). For each parcel (90 m by 90 m grid) of available land, the Technical Potential tool multiples the land area by power density (the needed landed area required for 1 MW of installed capacity [MW/km^2]) to calculate the installed nameplate capacity in MW for each region. Then, that nameplate capacity is multiplied by the capacity factor (calculated using hourly time series solar resource data [global horizontal irradiance (GHI) for PV and direct normal irradiance (DNI) for CSP]) and 8,760 hours in the year to get generation in MWh/year. For more information see the RE Data Explorer User Guide[6].

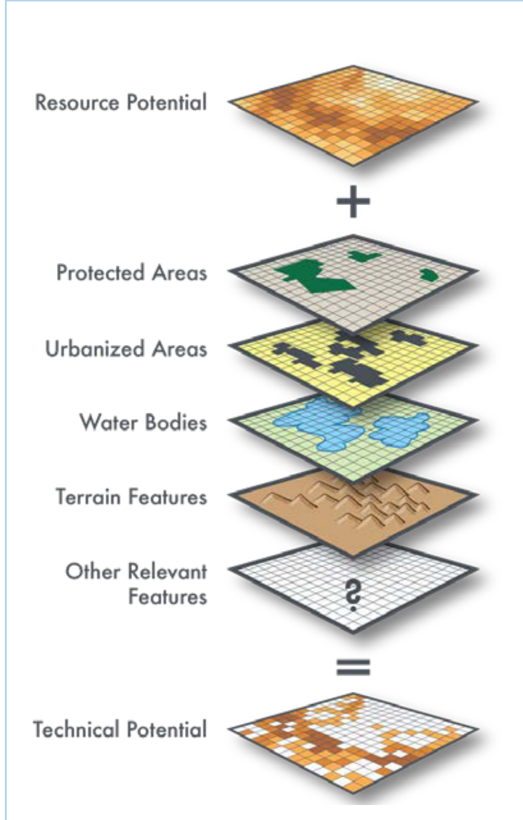

Figure 2: Geospatial down selection from resource potential to technical potential within RE Data Explorer

Inputs

The inputs into the technical potential tool incorporate minimum resource constraints (kWh/m^2/day), maximum allowable slope (in %), power density for a given technology (MW/km^2), maximum distance to transmission lines, maximum distance to roads, and land exclusion types. Resource and slope inputs were adapted from Lopez et al. 2012[7] and power density was calculated using Ong et al. 2013[8]. Since the publication of these papers, PV and CSP technologies have vastly improved so the inputs used in this analysis represent a conservative, lower-bound estimate. To minimize interconnection costs, the distance to transmission and road constraints were set at the lowest increment in the tool (5 km). Results from the technical potential tool can be used as a upper-bound estimate for available land and capacity for technologies. However, in this case, the inputs were designed to provide a conservative estimate of this upper-bound (i.e. looser constraints would result in higher land and capacity numbers).

Inputs	PV	CSP
Minimum solar resource (kWh/m^2/day)	4	5
Max slope (%)	5	3
Power density (MW/km^2)	30	25
Distance to transmission (km)	5	5
Distance to roads (km)	5	5
Land use exclusion types	Agricultural, Forest, Open Wildlands, Urban, Water/Wetlands/Ice, and Environmentally Protected areas	

[5] https://www.nrel.gov/docs/fy18osti/68899.pdf
[6] https://www.nrel.gov/docs/fy18osti/71532.pdf
[7] https://www.nrel.gov/docs/fy12osti/51946.pdf
[8] https://www.nrel.gov/docs/fy13osti/56290.pdf

Results

Analysis results show that there is immense technical potential for PV and CSP in Peru (see Table 1), even using conservative inputs. Even though the technical potential results identified little land area compared to the total land area of Peru, there is still the potential for large generation capacity (260 GW for PV and 136 GW for CSP) for each technology. Note that the results presented below are not cumulative and in many cases PV and CSP technologies may compete for the same land area. These results represent only the technical potential: the economic or market potential will be much lower depending on many factors (interconnection availability and cost, regulations, electricity prices, transmission congestion, etc.). These results represent a lower bound for the available land area and PV capacity.

Technical Potential Results	PV	CSP
Total Land (km^2)	8,616	5,437
Nameplate capacity (GW)	260	136
Generation (GWh/yr)	559,000	375,000

To put these results in perspective, in 2017 the Peru national grid (Sistema Eléctrico Interconectado Nacional [SEIN]) had an installed capacity of 7.5 GW (mostly hydro and natural gas) and generated 49,000 GWh[9]. Based purely on solar resource and land constraints from this analysis, Peru could generate roughly 10 times more annual electricity than is being generated today. However, it is very important to note that these results only represent the technical potential of PV and CSP, and a detailed grid modeling effort would be needed to determine the impact of these technologies on grid reliability and operation.

Figure 3. RE Data Explorer results for PV technical potential – each dot represents a 4 km x 4 km square that meets analysis constraints. Color corresponds to GHI bin.

Figure 4. RE Data Explorer results for CSP technical potential

As shown in Figure 3 and Figure 4, there are large geographical variations in available land area for both technologies. Non-available land area in the Sur (southern) region is likely limited by slope and distance to transmission and roads, while land area in the Amazon region is likely limited by land type (forest) and insolation values. However, even though this analysis does not show a parcel of land being available for solar production, that does not preclude investment. For example, the Iquitos region is looking at installing solar to offset high electricity prices and diesel use (Brancucci et al. Forthcoming), even though this analysis does not identify that region due to the distance to

[9]Inf.Anual 2017.pdf

transmission and roads exclusion and exclusion of forest lands in the analysis. A project-by-project assessment is needed to determine actual feasibility of land available for renewable energy development.

When the distance to transmission lines and roads constraint is removed, the available land area for PV jumps to roughly 40,000 km^2, a five-fold increase (Figure 5). This shows that there is also potential for distributed solar resources to provide power for remote and small communities not near roads and transmission lines.

Many constraints should be examined to determine the economic and market potential for PV and CSP technologies. These constraints include, but are not limited to, wholesale electricity prices, system interconnection costs, system constraints (i.e. transmission capacity, congestion, equipment upgrades, etc.), land availability and cost, geographical demand constraints, and regulations in Peru. A production cost model and economic dispatch model are needed to determine the "optimum" generation mix based on country goals, system costs, and grid constraints. Once an optimal generation dispatch is determined, a transient power flow model is needed to test electrical and operational reliability of that system.

Conclusions

Overall, this analysis suggests that the solar resource in Peru is conducive to robust solar market development; there is significant land area available for both PV and CSP development in Peru. However, grid operation, reliability, technology costs, transmission constraints, and resource availability should be examined on a project-by-project basis to determine project feasibility. The RE Data Explorer tool allow for an early-phase geographical analysis to assist developers and policy makers in determining areas to focus on PV and CSP development.

If you have any questions about the RE Data Explorer tool or this analysis please contact *James.McCall@nrel.gov.*

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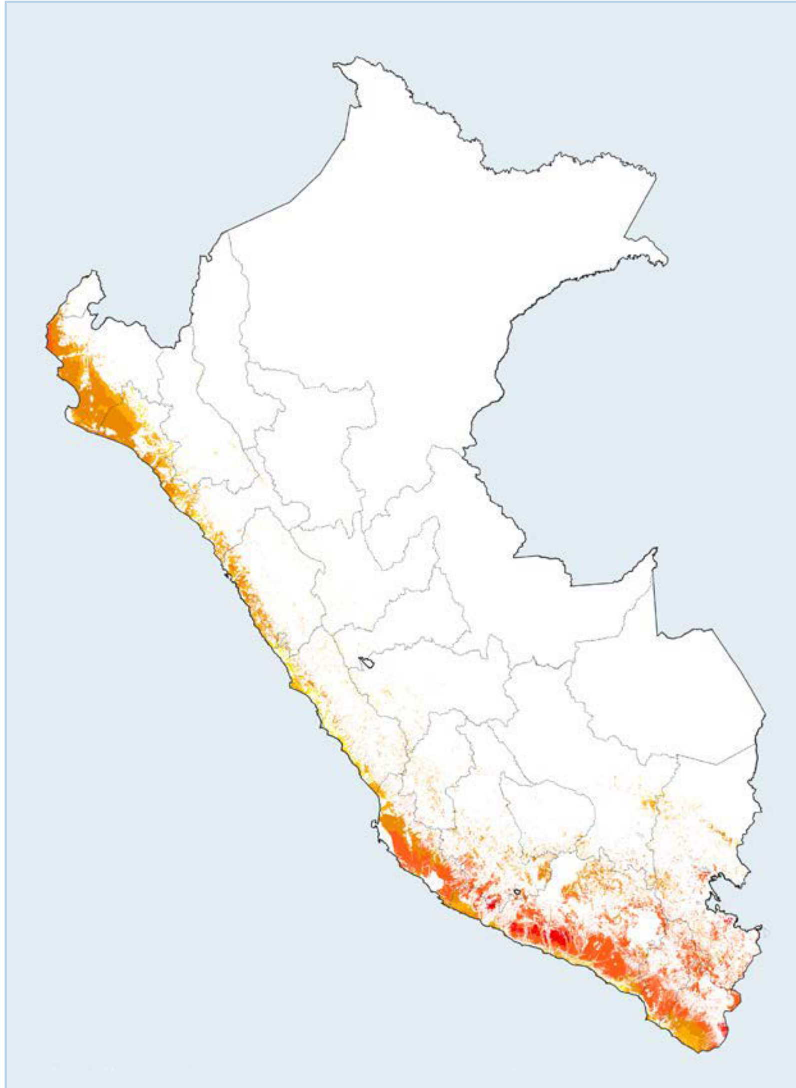

Figure 5. RE Data Explorer results for PV technical potential with distance to transmission and road constraints removed

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Renewable Energy (RE) Explorer provides renewable energy data, geospatial analysis tools, and technical assistance to support data-driven renewable energy decision making. The RE Explorer was developed by the National Renewable Energy Laboratory and are supported by the U.S. Agency for International Development.

The USAID-NREL Partnership addresses critical challenges to scaling up advanced energy systems through global tools and technical assistance, including the Renewable Energy Data Explorer, Greening the Grid, the International Jobs and Economic Development Impacts tool, and the Resilient Energy Platform. More information can be found at: **www.nrel.gov/usaid-partnership**.