

Multi-criteria Analysis for Planning Renewable Energy (MAPRE) initiative

INTERACTIVE MAP

India renewable energy zones (IREZ)

This interactive PDF map contains locations of high quality **wind, solar photovoltaic (PV), and concentrated solar power (CSP) zones** and estimated zone attributes important to the site-selection process (e.g., levelized cost of electricity; distance to nearest transmission lines, roads, and load centers; and proximity to load centers). Locations of existing or planned renewable energy power plants, substations, and load centers are also indicated on the map. In order to access different data layers and their attributes, this map must be opened using Adobe Acrobat PDF Readers, which are free to download. This interactive map can be used in conjunction with the Excel Renewable Energy Zone Ranking Tool. Data used in the map are from various sources, including Indian agencies, the National Renewable Energy Laboratory, and Vaisala Inc. Please refer to the accompanying report for methods, assumptions, and references for data sources. Spatial data used in this interactive map can be downloaded from the mapRE (<http://mapre.lbl.gov/>) website.

This map and its supporting study are the results of a collaboration between the Lawrence Berkeley National Laboratory (LBNL) and the University of California at Berkeley (UCB). © 2016.

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Boundaries and names shown in maps within the publication do not imply official endorsement by the International Renewable Energy Agency, the Lawrence Berkeley National Laboratory, or the University of California at Berkeley. The purpose of this map and its supporting study is to support high-level transmission and generation planning, and not to recommend specific project siting and land use decisions.

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HOW TO USE THIS MAP

VIEWING LAYERS

a) On the left hand side menu, click on the layers icon. 

b) Expand folders you wish to view. Individual layers are classified under three folders - INFRASTRUCTURE, RENEWABLE ENERGY ZONES, and DEVELOPMENT CONSTRAINTS.


c) Each layer within a folder can be turned “on” or “off” by clicking on the “eye” icon.  The legend on the right side of the map explains the symbology of each layer.

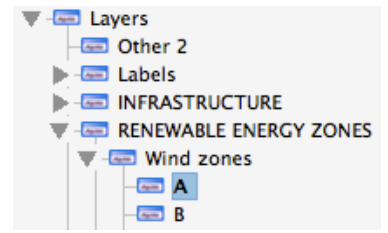
d) The renewable energy zones for each of the three technologies are colored by the estimated total levelized cost of energy (LCOE) for that technology. The legend on the right side of the map shows the corresponding LCOE costs (USD/MWh) for each color.

VIEWING ATTRIBUTES

The detailed attributes of each SEAREZ are embedded in this map. These attributes are described on page 5 of this interactive PDF. Below are two ways to access these attributes:

a) **Select Zone ID and retrieve attributes and location.**

The attribute table can be accessed for a zone by clicking on the Model Tree icon  on the left menu. Within the Model Tree, expand the folders of the layers containing the zones and select a zone ID (e.g., “A”). An example Model Tree folder structure is shown here (right). The attributes (e.g. levelized cost of energy for generation, transmission and roads, distance to load centers) for each zone will be displayed on the bottom, left menu, beneath the Model Tree folder structure once you click on the zone ID. An example attribute table is shown here (lower right). You may also locate this zone on the map by right clicking on the zone ID-> Zoom to Selection. This feature is useful for locating zones identified through the Multi-Objective Zone Ranking Tool.



Property	Value
OBJECTID	90
zone_identification	CL
electricity_generation_discounted_MWh	1971990.258745
area_km2	384.499998
LCOE_total_transmission_USDperMWh	65.125767

b) **Select location and retrieve attributes.**

Turn on the “Object Analysis Tool.” In Adobe Acrobat Reader X, this tool is under Edit -> Analysis -> Object Data Tool. In Acrobat Pro X, this tool is under Tools -> Analyze -> Object Data Tool. For other versions of Adobe Reader, please refer to Adobe’s documentation to find the Object Analysis Tool. For newer versions, refer to the Adobe Acrobat documentation. The Model Tree icon will appear on the left menu if it not already available. Once the Object Analysis Tool has been activated, the cursor changes to a “cross”. Move the cursor over a zone (or any other feature in the map), and click multiple times (giving at least a couple of seconds between each click). Each click opens a layer’s folder in order to retrieve the final zone ID and its attributes. The map may highlight all selectable areas in red in between mouse clicks. Only the selected zone should be outlined in red once its attribute table has been retrieved. Please keep in mind that this way of assessing attributes may be slow.

c) If a map has been georeferenced, the latitude and longitude coordinates in decimal degrees can be displayed for any location on the map by accessing the “Geospatial Location Tool,” found in the same menu as the “Object Analysis Tool.”

INDIA

RENEWABLE ENERGY ZONES

Total Levelized Cost of Electricity
CERC methodology (USD/MWh)

Wind	Solar PV	Solar CSP No storage
■ < 60	■ < 88	■ < 178
■ 60 - 64	■ 88 - 89	■ 179 - 180
■ 65 - 69	■ 90 - 91	■ 181 - 182
■ 70 - 74	■ 92 - 93	■ 183 - 184
■ 75 - 79	■ 94 - 95	■ 185 - 186
■ 80 - 84	■ 96 - 97	■ 187 - 188
■ 85 - 89	■ 98 - 99	■ 189 - 190
■ 90 - 94	■ 100 - 101	■ 191 - 192
■ 95 - 99	■ 102 - 103	■ 193 - 194
■ \geq 100	■ \geq 104	■ \geq 195

INFRASTRUCTURE

 Major cities  Roads

Renewable energy power plants




Operational Potential/proposed

Wind  Wind 








Solar PV  Solar PV 

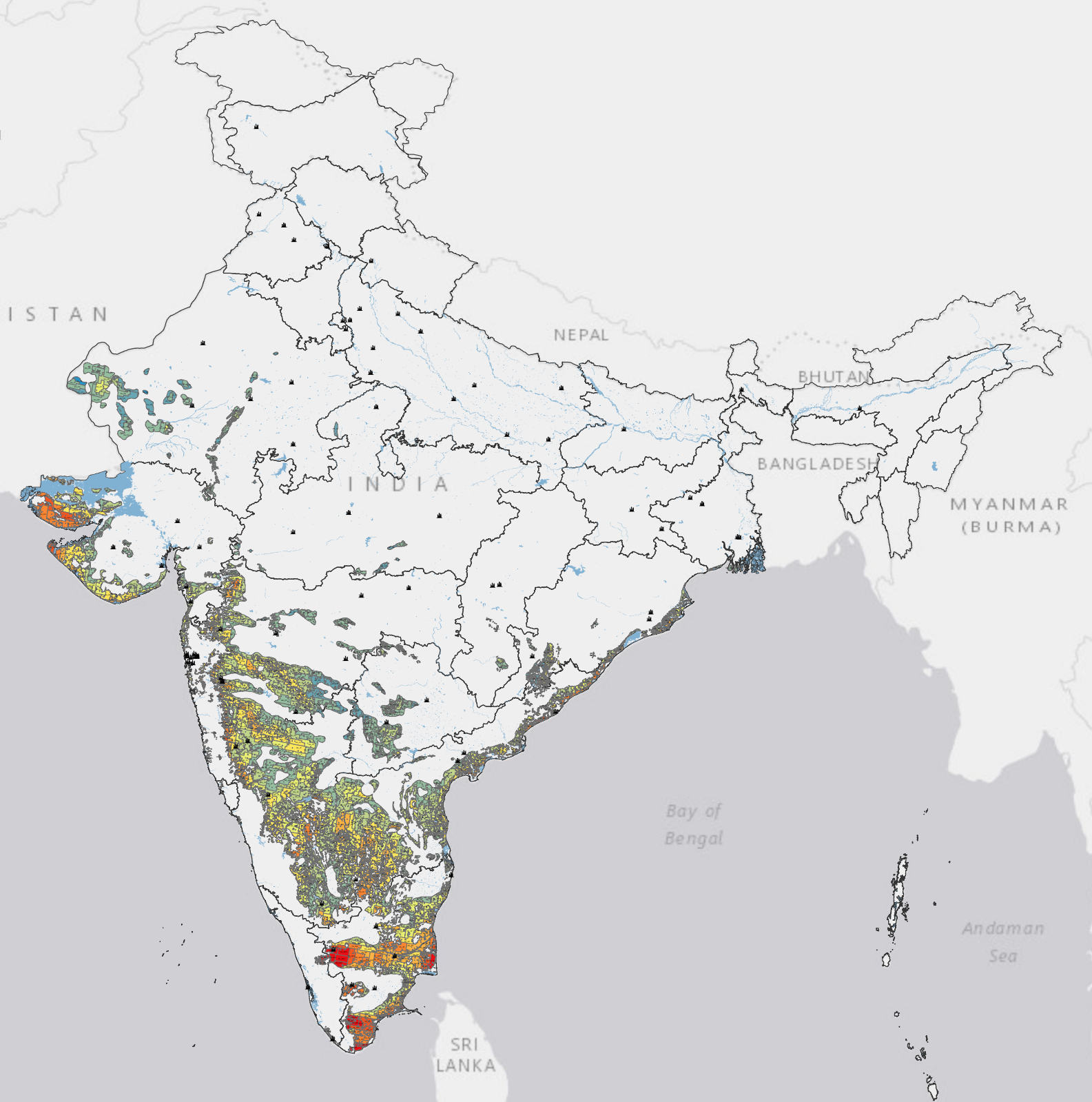
Substations

Maximum rating (kV)

 765
 400
 220 - 230

DEVELOPMENT CONSTRAINTS

 Protected areas
 Water bodies
 Elevation
 Slope (solar)
 Slope (wind)
 Land use \ land cover (solar)
 Land use \ land cover (wind)



ATTRIBUTE TABLE DESCRIPTIONS

The attribute table, once retrieved, will be displayed on the bottom, left-hand side of the Model Tree menu. Blue highlighted cells indicate attributes that are specific to wind zones, orange highlighted cells indicate attributes specific to solar CSP zones, and yellow highlighted cells indicate attributes specific to solar PV. All other attributes are common between technologies.

ATTRIBUTE NAME	DESCRIPTION
zone_identification	This is the unique alphabetical identifier for the zones. Zones are labeled on the map using this identifier. The first part of the identifier is the state abbreviation.
Electricity generation attributes:	Estimated annual average electricity generation in MWh for the following:
A) Electricity_generation_discounted_MWhPerYr	Solar PV , assuming a 90% land use discount factor.
B) Electricity_generation_discounted_chosenTurbine_MWhPerYr	Wind using the optimally selected IEC turbine class, assuming a 75% land use discount factor.
C) Electricity_generation_discounted_classII_turbine_MWhPerYr	Wind using IEC Class II turbines, assuming a 75% land use discount factor.
D) Electricity_generation_discounted_noStorage_MWhPerYr	Solar CSP without storage, assuming a 90% land use discount factor.
E) Electricity_generation_discounted_6hrsStorage_MWhPerYr	Solar CSP with 6 hours of storage, assuming a 90% land use discount factor.
Potential installed capacity attributes:	Potential capacity (MW) that could be installed within a zone for the following:
installedCapacity_MW	Solar PV or wind , assuming a 90% and 75% land use discount factor, respectively.
installedCapacity_noStorage_MW	Solar CSP without storage, assuming a 90% land use discount factor.
installedCapacity_6hrsStorage_MW	Solar CSP with 6 hours of storage, assuming a 90% land use discount factor.
area_km2	Total area of the zone in units of square kilometers
Levelized cost of electricity (LCOE) of non-generation components attributes:	Average levelized cost of electricity (in USD/MWh) for the non-generation components of the following (values are only reported if transmission or substation data could be procured):
A) LCOE_substation_USDperMWh	Solar PV , estimated using distance to the nearest substation, if available.
B) LCOE_road_USDperMWh	Solar PV , estimated using distance to the nearest road.
C) LCOE_substation_chosenTurbine_USDperMWh	Wind using the optimally selected IEC turbine, estimated using nearest substation.
D) LCOE_road_chosenTurbine_USDperMWh	Wind using the optimally selected IEC turbine, estimated using nearest road.
E) LCOE_substation_6hrsStorage_USDperMWh	Solar CSP with 6 hours of storage, estimated using nearest substation.
F) LCOE_road_6hrsStorage_USDperMWh	Solar CSP with 6 hours of storage, estimated using nearest road.
Levelized cost of electricity (LCOE) of generation component attributes:	Average levelized cost of electricity (in USD/MWh) for generation component of the following technologies (values were estimated using the location's capacity factor and efficiencies specific to the technology):
A) LCOE_generation_USDperMWh	Solar PV
B) LCOE_generation_CERC_USDperMWh	Solar PV using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool.
C) LCOE_generation_CERC_RsperMWh	Solar PV using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool. Costs expressed in Rupees per MWh using a 65 Rs = 1 USD exchange rate.
D) LCOE_generation_chosenTurbine_USDperMWh	Wind using the optimally selected IEC turbine class.
E) LCOE_generation_chosenTurbine_CERC_USDperMWh	Wind using the optimally selected IEC turbine class and the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool.
F) LCOE_generation_chosenTurbine_CERC_RsperMWh	Wind using the optimally selected IEC turbine class and the assumptions in the Indian Central

	Electricity Regulatory Commission's feed-in-tariff estimator tool. Costs expressed in Rupees per MWh using a 65 Rs = 1 USD exchange rate.
G) LCOE_generation_classII_turbine_USDperMWh	Wind using IEC Class II turbine.
H) LCOE_generation_classII_turbine_CERC_USDperMWh	Wind using IEC Class II turbine and the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool.
I) LCOE_generation_classII_turbine_CERC_RsperMWh	Wind using IEC Class II turbine and the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool. Costs expressed in Rupees per MWh using a 65 Rs = 1 USD exchange rate.
J) LCOE_generation_noStorage_USDperMWh	Solar CSP without storage.
K) LCOE_generation_noStorage_CERC_USDperMWh	Solar CSP without storage calculated using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool.
L) LCOE_generation_noStorage_CERC_RsperMWh	Solar CSP without storage calculated using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool. Costs expressed in Rupees per MWh using a 65 Rs = 1 USD exchange rate.
M) LCOE_generation_6hrsStorage_USDperMWh	Solar CSP with 6 hours of storage.
N) LCOE_generation_6hrsStorage_CERC_USDperMWh	Solar CSP with 6 hours of storage calculated using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool.
O) LCOE_generation_6hrsStorage_CERC_RsperMWh	Solar CSP with 6 hours of storage calculated using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool. Costs expressed in Rupees per MWh using a 65 Rs = 1 USD exchange rate.
Total levelized cost of electricity (LCOE) attributes:	Average total levelized cost of electricity estimated by summing the individual component LCOEs for generation, transmission line or substation (values are only available if data could be procured), and road for the following:
A) LCOE_total_substation_USDperMWh	Solar PV, estimated using the substation LCOE.
B) LCOE_total_substation_CERC_USDperMWh	Solar PV, estimated using the substation LCOE and calculated using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool.
C) LCOE_total_substation_CERC_RsperMWh	Solar PV, estimated using the substation LCOE and calculated using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool. Costs expressed in Rupees per MWh using a 65 Rs = 1 USD exchange rate.
D) LCOE_total_substation_chosenTurbine_USDperMWh	Wind using the optimally selected IEC turbine class, estimated using substation LCOE.
E) LCOE_total_substation_chosenTurbine_CERC_USDperMWh	Wind using the optimally selected IEC turbine class, estimated using substation LCOE and calculated using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool.
F) LCOE_total_substation_chosenTurbine_RsperMWh	Wind using the optimally selected IEC turbine class, estimated using substation LCOE and calculated using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool. Costs expressed in Rupees per MWh using a 65 Rs = 1 USD exchange rate.
G) LCOE_total_substation_classII_turbine_USDperMWh	Wind using IEC Class II turbine, estimated using substation LCOE.
H) LCOE_total_substation_classII_turbine_CERC_USDperMWh	Wind using IEC Class II turbine, estimated using substation LCOE and calculated using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool.
I) LCOE_total_substation_classII_turbine_CERC_RsperMWh	Wind using IEC Class II turbine, estimated using substation LCOE and calculated using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool. Costs expressed in Rupees per MWh using a 65 Rs = 1 USD exchange rate.
J) LCOE_total_substation_noStorage_USDperMWh	Solar CSP without storage, estimated using substation LCOE.
K) LCOE_total_substation_noStorage_CERC_USDperMWh	Solar CSP without storage, estimated using substation LCOE and calculated using the assumptions

	in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool.
L) LCOE_total_substation_noStorage_CERC_RsperMWh	Solar CSP without storage, estimated using substation LCOE and calculated using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool. Costs expressed in Rupees per MWh using a 65 Rs = 1 USD exchange rate.
M) LCOE_total_substation_6hrsStorage_USDperMWh	Solar CSP with 6 hours of storage, estimated using substation LCOE
N) LCOE_total_substation_6hrsStorage_CERC_USDperMWh	Solar CSP with 6 hours of storage, estimated using substation LCOE and calculated using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool.
O) LCOE_total_substation_6hrsStorage_CERC_RsperMWh	Solar CSP with 6 hours of storage, estimated using substation LCOE and calculated using the assumptions in the Indian Central Electricity Regulatory Commission's feed-in-tariff estimator tool. Costs expressed in Rupees per MWh using a 65 Rs = 1 USD exchange rate.
mean_slope_percent	Mean slope of the zone in units of percent rise.
mean_populationDensity_personsPerKm2	Mean population density of the zone in units of persons per square kilometer.
mean_HumanFootprint_0to100	Mean human footprint metric (0 - least human impact; 100 - most human impact)
mean_LULC_score	Mean score for land use/land cover categories in the zone. Scores range from 1 to 5, with 1 being most compatible for energy development and 5 being least compatible.
Mean_colocation_score	Mean score for the suitability of the zone for other renewable energy technologies. For example, the attribute table of a solar PV zone would display the colocation score calculated using the zone's overlap with wind and CSP potential. The score ranges from 0 to 1, with 0 being no overlap and 1 being overlap with both renewable technologies.
Num_projectsWithWaterAccess	Number of project opportunity areas within the zone that is within 10 km of surface water.
mean_resourceQuality_Wperm2	Mean resource quality in terms of wind power density or solar irradiance of the zone in units of watts per m ² .
mean_resourceQuality_kWhPerm2Day	Mean solar resource quality of the zone in units of annual average kWh per m ² per day.
Capacity factor attributes:	Mean capacity factor of the zone for the following (values range from 0 to 1):
A) mean_capacityFactor	Solar PV
B) mean_capacityFactor_chosenTurbine	Wind using the optimally selected IEC turbine class.
C) mean_capacityFactor_classII_turbine	Wind using IEC Class II turbine.
D) mean_capacityFactor_noStorage	Solar CSP without storage.
E) mean_capacityFactor_6hrsStorage	Solar CSP with 6 hours of storage.
area_chosenTurbine_classIII_km2	Area (in km ²) within the zone for which IEC class III turbines would be most suitable
area_chosenTurbine_classII_km2	Area (in km ²) within the zone for which IEC class II turbines would be most suitable
area_chosenTurbine_classI_km2	Area (in km ²) within the zone for which IEC class I turbines would be most suitable
Distance attributes:	Distance to the nearest following locations (in units of kilometers):
A) distance_nearest_transmission_km	Transmission line
B) distance_nearest_substation_km	Substation
C) distance_nearest_road_km	Road
D) distance_nearest_existingPlanned_wind_km (or distance_nearest_existingPlanned_PV_km, distance_nearest_existingPlanned_CSP_km)	Operational or planned wind (or solar PV, solar CSP) power plant.
E) distance_nearest_anyRenewableEnergyLocation_km	Operational or planned renewable energy (wind, solar PV, solar CSP, geothermal) power plant.
F) distance_nearest_majorCity_km	Major city or load center.

G) distance_nearest_waterSource_km	Surface water (lake or river) source.
H) distance_nearest_boundary_km	Country boundary
Capacity value attributes:	
A) distance_nearest_3TierWindLocation_km	From the centroid of the zone, distance in km to the nearest location where simulated wind speed time series data were acquired from 3Tier. Hourly time series were used to estimate capacity value ratios.
B) capacityValueRatio_10percentPeakHours	The ratio of the capacity factor for the top 10% of hours with the largest electricity demand within a year (876 hrs) to the capacity factor of all hours within the same year (8760 hrs).
C) capacityValueRatio_chosen3peakHours	The ratio of the capacity factor for the daily top 3 hours with the largest electricity demand across an entire year (1095 hrs) to the capacity factor of all hours within the same year (8760 hrs).
D) capacityValueRatio_chosen3peakHours_multiyear	The ratio of the capacity factor for the daily top 3 hours with the largest electricity demand across an entire year, extrapolated to 10 years (10,950 hrs), to the capacity factor of all hours within the same 10 years (87,600 hrs). 3Tier provided 10 years of hourly time series data for each point location.
E) adjustedCF_top10percent	The capacity factor of the top 10% of hours with the largest electricity demand within a year (876 hrs). This value was estimated by multiplying the capacityValueRatio_10percentPeakHours with the mean_capacityFactor_chosenTurbine.
F) adjustedCF_top3hrs	The capacity factor of the daily top 3 hours with the largest electricity demand across an entire year (1095 hrs). This value was estimated by multiplying the capacityValueRatio_chosen3peakHours with the mean_capacityFactor_chosenTurbine.