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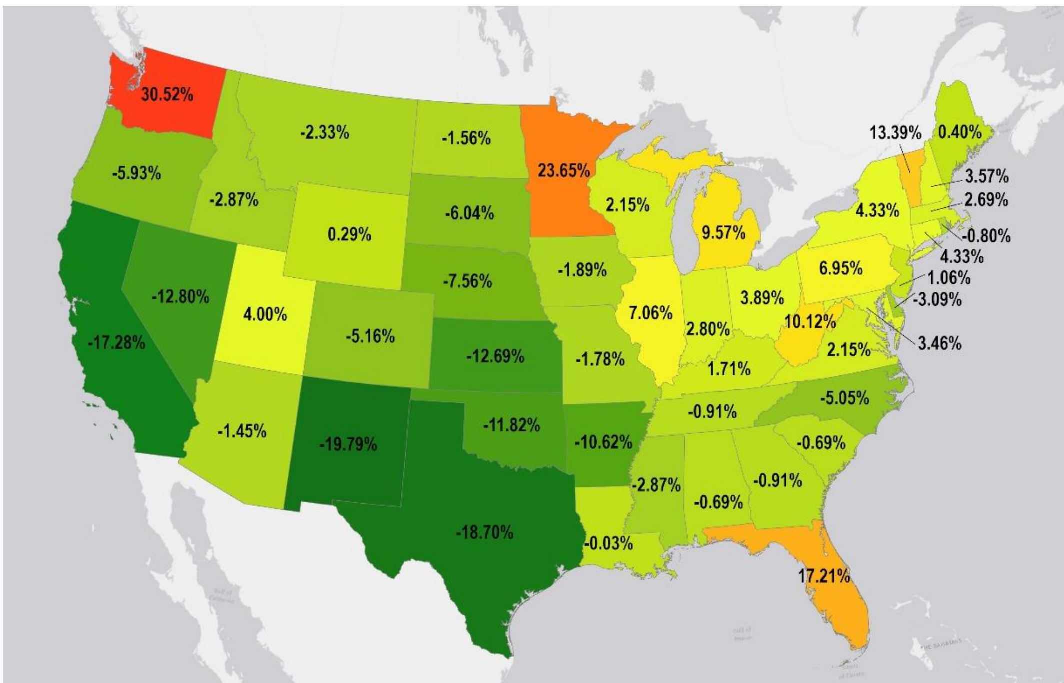

LEVELIZED COST OF RENEWABLE ENERGY IN THE LOWER 48 UNITED STATES: BLENDED SOLAR AND WIND

RELEASE VERSION 1.1

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Contents

1 Executive Summary 3
2 Introduction 4
3 Baseline Solar 4
3.1 Solar Simulation Set-up 4
3.2 Baseline Solar Sites and Results 5
3.2.1 Kingman, AZ 5
3.2.2 Bellingham, WA 5
4 Baseline Wind 5
4.1 Wind Simulation Set-up 6
4.2 Baseline Wind Sites and Results 6
5 Solar and Wind Analyses of 96 Sites 6
5.1 Potential Power Production 6
5.2 Financial Variables 6
5.2.1 Labor Costs 6
5.2.2 Land Costs 7
5.2.3 Tax information 8
5.2.4 Equipment 8
5.3 Calculating LCOE 9
6 Environmental losses 9
6.1.1 Solar 10
6.1.2 Wind 10
7 Simulation Results 10
7.1 Study LCOEs vs. Today's Competitive PPA Rates 10
7.2 Solar Analysis 11
7.3 Wind Analysis 12
7.4 Combined LCOE Analysis 12
7.4.1 50/50 LCOE Average Analysis 13
7.4.2 Weighted LCOE Average Analysis 14
7.4.3 Weighted vs. 50/50 Average Discussion 15
8 Comparison to NREL and UC Berkeley LCOE estimates 16
9 Conclusion 17
10 References 18
Appendix A. Sites Selected, by State 20
Appendix B. Site Specific Variables 22
Appendix C. U.S. Lower 48 Map of Wind Power Production 23
Appendix D. U.S. Lower 48 Map of Solar Power Production 24

1 Executive Summary

Multiple analyses that present the wind and solar capacities across the United States have been published for decades. National Renewable Energy Laboratory's (NREL) wind resource maps were first introduced by Pacific Northwest Laboratory in 1986 [1] and have been augmented more recently by studies from The University of Wyoming [2] and the National Resource Defense Council [3]. None of these studies, however, directly compare real levelized cost of electricity (LCOE) from wind and solar plants on a state by state basis. The purpose of this report is to provide a comparison of wind and solar energy *costs* to enable companies to make more informed location decisions based on renewable energy needs and specifically discuss New Mexico's results.

The results presented in this report show that for a 50% solar/50% wind generation portfolio, New Mexico has the lowest cost of renewable electricity in the U.S. at the grid interconnection point, at 19.79% below the national average.

This study was commissioned by Agenda, LLC and RePower New Mexico, and conducted by KiloNewton. The study's objective was to analyze solar and LCOE for favorable power plant sites located in each of the lower 48 contiguous states, to determine the lowest blended cost location for wind and solar electricity. For companies seeking the lowest cost 7 x 24 x 365 "always on" renewable electricity costs, a blended generation portfolio will typically provide the optimal solution.

Sites in each state were chosen using the National Solar Radiation Database (NSRDB) and NREL's Wind Prospector. NREL's System Advisor Model (SAM) software was used to model all sites for power production (PP) and costs. The validity of these PP results was confirmed using industry-leading software PVsyst and Openwind. The results correlated within 0.6% in high resource sites and 1.6% in all cases. Localized variables such as wind and solar production, land and labor costs, taxes, and environmental losses were included in the model to differentiate states' LCOE, while commodity, BOS, and overall costs were constant and aligned to national averages.

In addition to ranking first in 50/50 mix, New Mexico ranked fourth in when considering weighted average of current generation capacity, at 16.78% below national average. **New Mexico also appeared in the top five of every category considered in this study (all modeled LCOEs and PP).** A summary table of the top five calculated LCOEs for each state is shown in Table 1.

In summary, this study shows that **New Mexico consistently ranks as an ideal state to build solar and/or wind farms with the lowest LCOEs in the nation, and is *the* top contender with lowest LCOE for a 50/50 mix of combined solar and wind energy.**

Table 1: Top 5 states LCOE deltas from U.S. mean, ranked by 50% solar/50% wind and historical mix of production

Rank	50/50 mix		Weighted mix	
1	**NM**	**-19.79%**	SD	-20.51%
2	TX	-18.70%	KS	-20.08%
3	CA	-17.28%	TX	-17.29%
4	NV	-12.80%	**NM**	**-16.78%**
5	KS	-12.69%	ND	-16.20%

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2 Introduction

Agenda, LLC and Repower New Mexico requested KiloNewton provide a solar and wind analysis of numerous sites throughout the continental U.S. These analyses use local renewable resource data, weather, land and labor costs, taxes, and environmental losses for each specific site, while holding equipment selection, and other balance of system costs constant. Sites near the highest and lowest power production potential were more thoroughly examined to show the accuracy of the SAM production estimate, using results generated by renewable energy software. Determining these site locations was done by examining site specific parameters with PVsyst with SolarAnywhere weather data, and UL's Openwind software with reanalysis data from NASA's MERRA-2 database and the European Centre for Medium-Range Weather Forecasts' (ECMWF) ERA5 database. System Advisor Model (SAM) was used to model both solar and wind sites for both production and economic analysis. SAM production results were compared and calibrated to match PVsyst for solar analyses, and Openwind for wind analyses. Initially, these four sites are presented to give a preliminary analysis of the validity of the SAM results. Then, 96 sites were analyzed, along with specific economic and labor costs for each site using the same base SAM model. These sites will be compared based on their power production potential and LCOE, which can be used to show ideal locations using a typical renewable energy design.

It is notable that absolute values of the LCOE results without tax incentives in the report are often much higher than Power Purchase Agreement (PPA) prices found in the news today. The discrepancy in reported LCOE cost vs. today's lowest available PPA costs is due to many factors, including current renewable tax credits, site specific optimizations and costs, and continuing efficiency improvements. A more detailed examination of this is presented in Section 7.1, where the results of an LCOE study are presented with higher efficiencies, tax credits and the lowest reported costs on a site.

It is also important to note that the LCOE costs presented are based on reported national averages, which may only include minor transmission upgrades, if any at all. The cost to deliver electricity from power plant to a specific site requires levels of complexity that are beyond the scope of this report, and local utility transmission experts should be consulted for any large site to determine cost and feasibility for that location.

3 Baseline Solar

To validate the solar models, two locations were chosen to bracket "high" resource and "low" resource. The high resource was chosen near Kingman, Arizona, a well-known high solar resource area with many solar farms. The low resource was chosen near Bellingham, Washington which has some of the lowest irradiance values in the country and no large utility scale solar farm developments in the area. To validate the SAM model, the two locations were also implemented in PVsyst software.

3.1 Solar Simulation Set-up

The technical set-up of this simulation is the same for both locations having a total of 351,351 Jinko Solar JKM370M-72L-V (370W) modules, covering 674,593 m^2 total area and a total of 40 SMA SC 2500-EV-ES inverters (2.5MW), yielding a 1.38 DC to AC ratio. They were wired with 27 modules per string initially, with 13,013 total strings in parallel. The string sizes are automatically redesigned for each location's temperature conditions. The mounting models simulated a single axis tracker oriented with a zero-degree azimuth and tilt, given a maximum tilt value of ±52 degrees, and backtracking capabilities. Losses due to soiling were set at a baseline of 2%, and adjusted for snow as detailed later in 6.1.1. All other loss settings were left at default values. Each site was modelled using averaged 10-year solar weather data from Solar Anywhere, for a 10-km square parcel on or adjacent to the town where a solar farm could be built.

3.2 Baseline Solar Sites and Results

3.2.1 Kingman, AZ

Kingman is in the west-central part of the Arizona and already has large solar farms near the city. Sites in the Southwest are generally excellent locations for harnessing power with solar modules. This location has a global horizontal irradiance (GHI) value of 2095 $\frac{kWh}{m^2}$ and has clear sunny days most of the year. The yearly power production in both simulations was over 299 MWh and had an error of 0.09% between them. Table 2 shows the power produced in each case and the calculated difference.

Table 2: Solar simulation comparison Kingman, AZ

Overall Power Production MWh		**Percent Difference**
PVsyst	299,717	0.09%
SAM	300,001	

3.2.2 Bellingham, WA

Bellingham is in Northwest part the of Washington state. Large solar farms are virtually nonexistent in this locality as cloud cover is common and has a much lower GHI. This location has a GHI value of 1217 $\frac{kWh}{m^2}$. The yearly power production in both simulations was over 170 MWh and had an error of 0.56% between them. Table 3 shows the power produced in each case and the calculated difference.

Table 3: Solar simulation comparison Bellingham, WA

Overall Power Production MWh		**Percent Difference**
PVsyst	172,613	0.56%
SAM	171,646	

4 Baseline Wind

To validate the wind models, two locations were chosen to bracket “high” resource and “low” resource. The high resource was chosen near Sweetwater, Texas, which is a well-known high wind resource area with dozens of wind farms. The low resource was chosen near Albany, Georgia, which has some of the lowest winds in the country and no wind farm developments in the area. NREL’s SAM software was again used to estimate wind resource and LCOE. To validate the SAM model, the two locations were also analyzed in UL’s Openwind software, which is an industry-standard wind flow and wind farm modeling package.

4.1 Wind Simulation Set-up

In Openwind, representative wind resource models were created using a combination of NASA's MERRA-2 data and the ECWMF ERA5 data at various nodes surrounding the chosen locations. The frequency distributions from these nodes were input into Openwind to create a representative wind resource at multiple heights. It is noted that to perform a full wind resource analysis, this method is not ideal. On-site measurements are needed to fully ascertain an accurate wind flow model. However, for the purposes of this project to compare high level wind resources at a state level with the SAM model, using the reanalysis data from MERRA-2 and ERA5 will suffice.

Once the wind flow models were run, a layout based on the frequency distribution and the best wind locations in the chosen areas were created for each site. Standard losses were applied in Openwind for availability, turbine performance, environmental, and electrical. Curtailment losses and wake from external wind farms (current or future) were not considered. The same losses were input into the SAM model. Wake losses were calculated in Openwind and SAM using the Eddy-Viscosity model.

4.2 Baseline Wind Sites and Results

For both projects, the Vestas V110 2.0 MW turbine was used to model the wind resource at 80 m. The difference between the calculated Net Capacity Factors (NCF) was **0.6%** for Texas and **1.6%** for Georgia.

5 Solar and Wind Analyses of 96 Sites

Sites were chosen for each state to analyze its power production for solar and wind farms. Requirements for a site to be considered were established, and 96 sites were chosen throughout the U.S. that met all requirements. The requirements each site needed to meet were as follows: less than a 10-mile proximity for transmission; an ideal location for wind or solar; and outside of high cost land markets, such as agricultural or mixed-use sites. After each site was chosen, labor, land, transportation, transmission, equipment, and solar/wind costs were determined. These costs varied from site to site as they are in different states and cities. Lastly, sites were analyzed using the same set-up as earlier studies conducted in this report. Locations for each power plant can be found in Appendix A.

5.1 Potential Power Production

Irradiance and wind speeds very greatly throughout the country and across in individual states. Sites were chosen using the most ideal location in the state where building a solar or wind farm was feasible using the National Solar Radiation Database (NSRDB) and NREL's Wind Prospector. For example, the state of New Mexico, Deming and Vaughn (east-southeast of Albuquerque) were chosen as ideal sites for solar and wind, respectively. Irradiance and wind speed values for NM with the sites circled can be seen in Figure 1.

5.2 Financial Variables

Financial costs were examined for each state. This was done using a variety of sources and methods given below. Analyzing each state in detail gave a more accurate localized LCOE value and overall cost.

5.2.1 Labor Costs

General construction rates for each state were gathered from the U.S. Bureau of Labor Statistics [4]. The average $/hour rate of construction labor throughout the country was calculated. Then, a ratio cost of labor per state was determined by dividing the states cost of labor by that average. For solar sites that

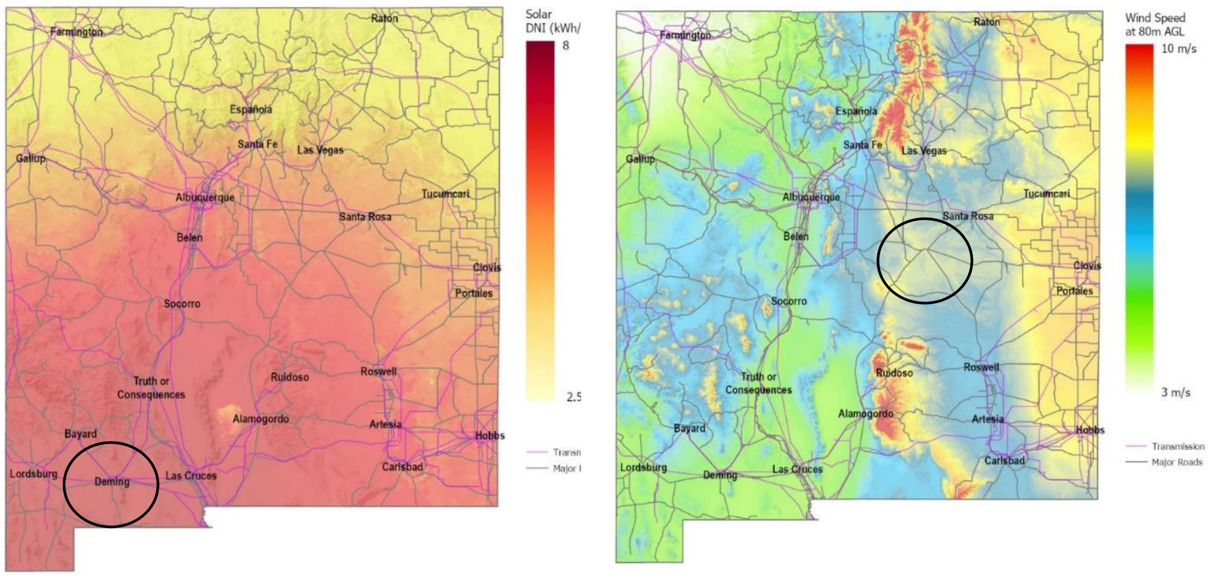

Figure 1: Average annual irradiance and wind speeds throughout NM

calculated ratio is multiplied by \$0.10/W, the average cost of labor reported by NREL in \$/kWh [5]. For example, for a state whose average construction labor cost was 80% of the U.S. average (\$0.08/W) was used for construction labor in the calculation. This resulted in a cost of labor in \$/kWh for each state and were input to each appropriate SAM simulation, as detailed in Appendix B.

For wind energy, that same ratio of state labor rates to nationwide labor rates was multiplied by the average cost labor for wind, \$90/kW, which was estimated based on NREL installation cost data [6]. Then, that number was used to adjust the total balance of system equipment (BOS) cost also reported by NREL at 332 $\frac{\$}{kW}$, for each state to input in SAM. Non-labor BOS costs amount to \$242 $\frac{\$}{kW}$, and so the adjusted labor rates are added to this amount. A sample calculation is shown below for New Mexico in equation (1).

$$(1)\ 242\frac{\$}{kW} + \left((Labor\ ratio) * \left(Wind\frac{\$}{kW}\right)\right) = 242\frac{\$}{kW} + (0.8288 * 90) = 316.59\frac{\$}{kW}$$

5.2.2 Land Costs

Average cost of land per acre was gathered from the U.S. Department of Agriculture (USDA) Summary of Land Costs 2019 [7]. This data contained every state's cost of pastureland per acre, except for Arizona, and Nevada. Values were assigned to those two states using the average cost of regional land collected from a summary conducted by the USDA. It provides costs of farm real estate, cropland, cropland rent, pasture value, and pasture rent [8]. Land cost vs. rent data was given by region, where the region is defined for each state in Appendix B, and therefore a percentage cost of renting land vs buying was determined by dividing the "cost of buying land per acre" by "yearly cost to rent" per acre. An example using the Mountain State region is shown in equation (2).

$$(2)\left(\frac{\$5.30}{\$683}\right) * 100\% = 0.78\%$$

For the Mountain State region, the cost of renting is calculated to be 0.78% of buying land.

This operation was performed for each region. The percentage calculated was then multiplied by every state's cost of land in that region to find a dollar per acre value for yearly rent. Sample results for Mountain States and New Mexico are shown in Table 4.

Table 4: Prices of land in the mountain state region

Region	**Pasture per acre (buy)**	**Pasture per acre (yearly rent)**
Mountain States	$683	$5.30
New Mexico	$417	$3.25

5.2.3 Tax information

State sale taxes are dependent on the state, and some are exempt from sales taxes [9]. This report uses SAM's default Federal income tax of 21%/year [10]. Project term debt, financing, revenue, and depreciation parameters were identical in each site's set-up, using default values in the SAM software where possible. Lastly, this analysis does not include any government incentives, both Federal and state in any tax.

5.2.4 Equipment

Equipment costs for each power production method were set accordance with standards set by NREL. For solar power generation, operations and maintenance (O&M), direct and indirect capital costs were gathered from NREL's benchmark of solar energy costs [5]. These costs were identical in each SAM site simulation. For wind power generation a similar report from the NREL was referenced for system costs [6]. A summary of the equipment, labor, and other BOS cost baselines for each power plant is shown below for solar in Table 5 and Table 6, and for wind in Table 7 and Table 8.

Table 5: Equipment and other costs of solar installation

Solar Equipment and other costs [5]	**Cost ($/Wdc)**
Module	0.47
Inverter	0.05
BOS	0.15
Installer and margin overhead	0.10
Permitting and environmental studies	0.06
Engineering and developer overhead	0.03
Grid interconnection	0.01
Land prep and transmission	0.02

Table 6: Solar O&M costs

Solar Operation and Maintenance	Cost
Fixed annual cost (Renting land)	Dependent by state ($/yr)
Fixed cost by capacity	14 $/kW-yr

Table 7: Wind equipment and other costs

Wind Equipment and other costs [6]	**Cost ($/kW)**
Wind turbine	1011
BOS	332

Table 8: Wind O&M costs

Wind Operation and Maintenance	Cost
Fixed annual cost (Renting land)	Dependent by state ($/yr)
Fixed cost by capacity	44 $/kW-yr

5.3 Calculating LCOE

The LCOE is used to determine the cost of generating power and determining the overall financial feasibility of a project. Using this allows for comparisons between power sources like wind and solar. SAM automatically calculates this value for both real and nominal values. Nominal refers to a constant value for the dollar. Real LCOE accounts for the change in value of the dollar over time (inflation).

The LCOE Calculator uses a simple fixed-charge rate (FCR) method to calculate a project's LCOE for each year, which is then calculated for net present value and inflation, using the following inputs:

- Capital cost, $ (TCC)
- Fixed annual operating cost, $ (FOC)
- Variable operating cost, $/kWh (VOC)
- Fixed charge rate (FCR)
- Annual electricity production, kWh (AEP)

The LCOE Calculator uses equation (3) (3) to calculate the LCOE [11]:

$$(3)\ \text{LCOE} = \frac{(\text{FCR} * \text{TCC}) + \text{FOC}}{(\text{AEP} + \text{VOC})}$$

6 Environmental losses

Temperature, humidity, and precipitation varies greatly across the continental U.S. Therefore, losses due to these weather differences were applied to each site dependent on their own climate. Data was gathered, analyzed and put in the proper form required by SAM software.

6.1.1 Solar

A percentage of loss due to snow was calculated and applied to SAM's soiling losses. This was done by first determining the loss of power production (PP) in relation to a standard soiling loss (2%) without snowfall, for each site. Then, a simulation was run to determine the percent loss of PP with snowfall data from the National Operational Hydrologic Remote Sensing Center (NOHRSC) [12], but not soiling. This value was then multiplied by ratio of soiling loss percent and PP loss. This percent value was then added to the standard 2% soiling loss for each site. This method resulted in less than 1% error in PP with snowfall and soling included in the simulation.

6.1.2 Wind

Monthly 30-year normal mean temperature, mean dew point, and minimum vapor pressure deficit GIS layers were acquired for the United States from the PRISM Climate Group [13].

Each layer was reclassified on a scale from 0 to 4 to help ascertain the potential for icing buildup on wind turbine blades, with 0 being no possibility and 4 being the highest possibility. Each monthly reclassified layer was multiplied by the other layers to create a scale of potential icing in each month. If one layer is 0 for a month, then there is no possibility of icing. The resulting monthly layers were then summed to get an annual layer, with higher numbers reflecting more frequency of potential icing in a normal year.

Typically, icing losses for a wind farm are between 0%-4% across the United States (although some areas, such as Alaska or North Dakota could see higher values). Midwest losses (for example, Illinois and Indiana) are typically around 2%. The results of the summation of the monthly layers were then converted to percentages.

7 **Simulation Results**

Wind and solar simulations were run in SAM using the procedures and values mentioned above and their annual power production and the LCOE were recorded. These results in their entirety can be seen in Appendix B. LCOE is the cost of energy per kWh (¢/kWh). This value is used to determine the general financial feasibility of a solar or wind project. SAM automatically calculates these values and a summary is given below.

7.1 Study LCOEs vs. Today's Competitive PPA Rates

To compare how these average values might relate to the lowest-cost competitive PPA rates today, an LCOE sensitivity was calculated including wind and solar PTC/ITC tax credits, cutting-edge module efficiencies, and lower site costs. All technical parameters remained the same for both wind and solar sites, except the solar module, which was changed to a Jinko Solar JKM410M-72HL. Losses for both sites were optimized to create an annual power production approximately 10% higher than the original simulation. For the solar site, the cost of the system was lowered from 0.92 $/kWdc to 0.52 $/kWdc to represent record-low installation costs. Lastly, the solar site was set to receive a 30% Investment Tax Credit (ITC) from the federal government. For wind, the system cost was lowered from $1327.60/kW to $1027.60/kW by adjusting the turbine and BOS cost and given a Production Tax Credit (PTC) of 2.2¢/kWh for 10 years. These adjusted simulations show real LCOE values that are more closely aligned with highly competitive PPA prices today. The LCOEs of these two simulations are compared to the originals for New Mexico and are shown below in Table 9.

Table 9: Average non-incentive LCOE vs. adjusted for extreme optimized example

Site type	Original simulation real LCOE (¢/kWh)	Adjusted simulation real LCOE (¢/kWh)
Wind	3.58	1.68
Solar	3.77	1.84

7.2 Solar Analysis

After all simulations were run, each site's power production and LCOE was analyzed. The top five power production and lowest LCOE states are given below. Table 10 and Figure 2 give a summary of the solar LCOE results.

Table 10: Top 5 states power production and LCOE solar

State	Power Production (MWh/year)	State	LCOE (¢/kWh)
TX	257614	CA	3.74
CA	256116	NM	3.77
NM	255388	TX	3.86
NV	252165	AZ	3.89
AZ	249763	NV	3.95

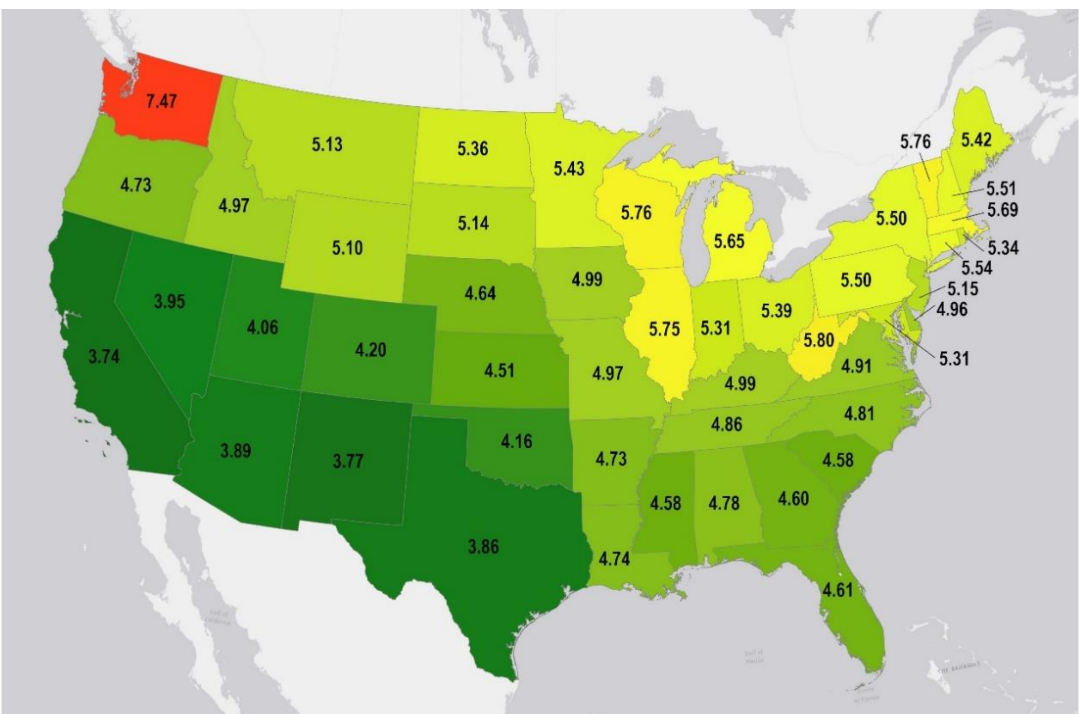

Figure 2: Solar LCOE ¢/kWh

7.3 Wind Analysis

After simulations were preformed, each site's power production and LCOE was analyzed. The top five power production and lowest five LCOE states are given below. These states have the most financially feasible sites for constructing a utility sized wind farm. Additionally, while comparing without incentives, ~ 60% of states show less expensive LCOE than solar farms and about 63% of these states have a lower LCOE than traditional coal fire power plants [11]. Table 11 and Figure 3 give a summary of wind LCOE results.

Table 11: Top 5 states power production and LCOE wind

State	**Power Production (MWh/year)**	**State**	**LCOE (¢/kWh)**
SD	359464	AR	3.46
KS	348662	SD	3.47
AR	348460	KS	3.49
TX	347768	NM	3.58
NM	338988	TX	3.59

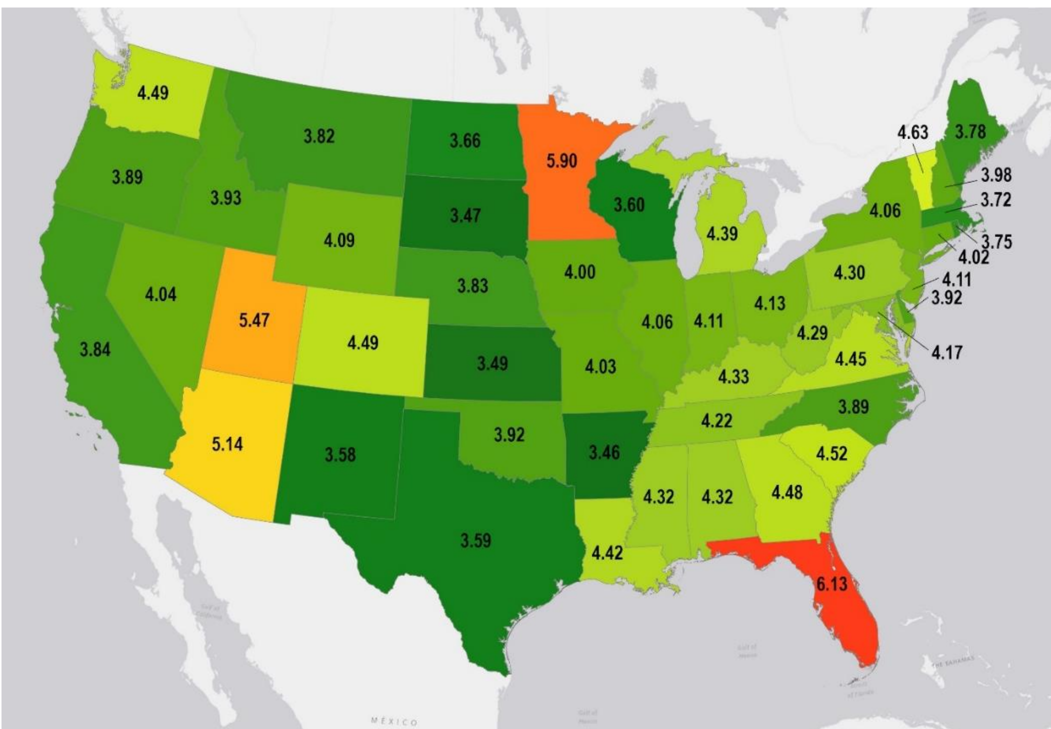

Figure 3: Wind LCOE ¢/kWh

7.4 Combined LCOE Analysis

To better understand the LCOE for each state, wind and solar values are analyzed together to determine an overall LCOE. This was done using two methods, a standard 50/50 average of solar and wind LCOE, and a weighted average using current installed solar and wind farms throughout the lower 48 states.

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The nationwide 50/50 and weighted averages were compared to each state's 50/50 or weighted average. A percent difference was calculated to show what states are over (positive percent), or under (negative percent) the national averages provided by the SAM simulations. The results for each case are given below in Figure 4 & Figure 5 . In addition, and a sample calculation, equation (4), for calculating the percent difference is shown below.

(4) ((State Average/Nation Average) – 1) * 100% = Percent Difference

7.4.1 50/50 LCOE Average Analysis

This method uses the wind and solar LCOE for each state. Then, taking the average between the two values, gives an overall cost of energy for both wind and solar energy sources. Take for example the state of Florida, a state with low solar LCOE but one of the highest LCOE when dealing with wind. Equation 4 shows this process. Table 12 provides a summary of the top five states' LCOEs and their percent differences using this method and Figure 4 shows the 50/50 percent differences throughout the country.

Florida Average LCOE:

Wind = $6.15\,\frac{¢}{kWh}$

Solar = $4.61\,\frac{¢}{kWh}$

(5) $Average\ LCOE = \frac{6.15+4.61}{2} = 5.38\frac{¢}{\mathrm{kWh}}$

Table 12: Top 5 states 50/50 average LCOE

State	50/50 Average LCOE (¢/kWh)	Percent Difference from nation average
NM	3.68	-19.79%
TX	3.73	-18.70%
CA	3.79	-17.28%
NV	4.00	-12.80%
KS	4.00	-12.69%

This method is useful is determining an LCOE for projects that will use relatively even mixtures of solar and wind energy. However, it does not accurately capture the weighted average based on historical local preference for a specific type of energy. To account for this, a weighted average analysis was conducted, described in Section 7.4.2 below.

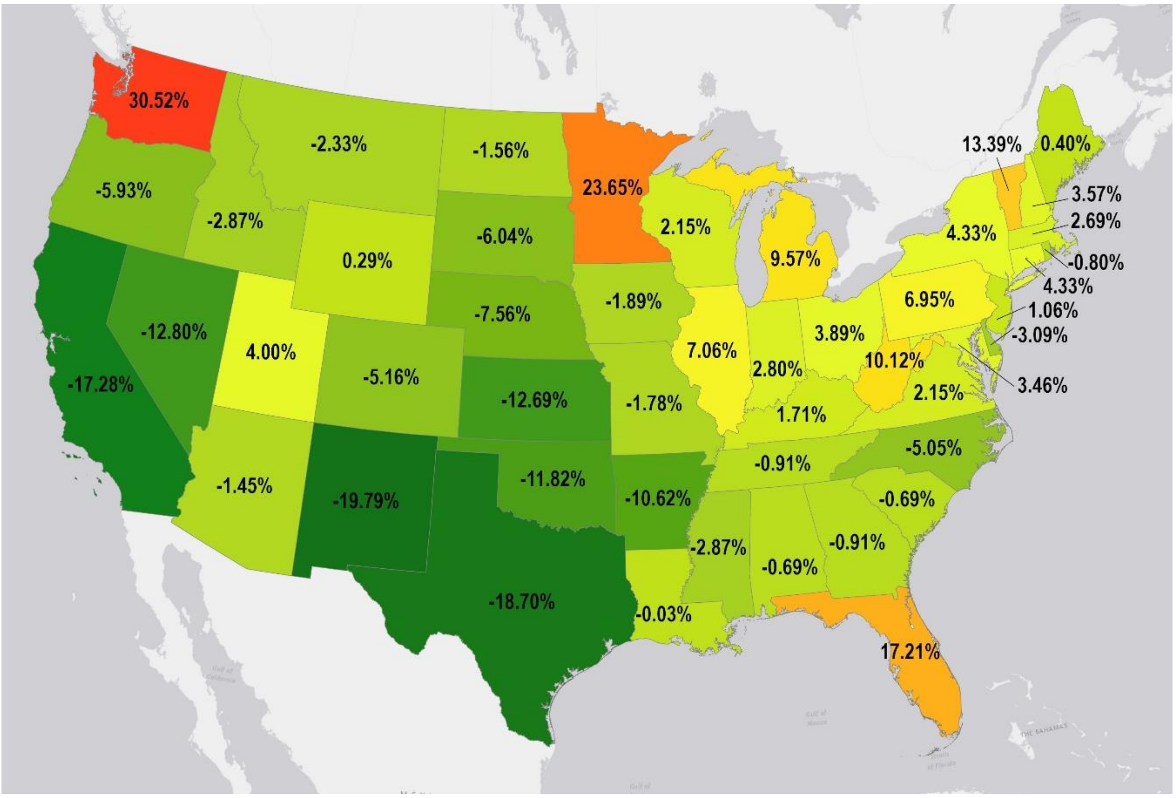

Figure 4: U.S. map of percent difference costs from national average using 50/50 average LCOEs

7.4.2 Weighted LCOE Average Analysis

To analyze the costs of installed solar and wind energy capacities using the historical trends for the type of energy installed, a weighted balance of wind and solar was used to calculate LCOE. States with a higher level of installed wind energy can be assumed to already have a more robust wind development pipeline and process, equipment and trained labor readily available, and vice versa for solar farms. Data on current installed capacity was gathered from the Energy Information Administration [14]. Using this database, total capacities were tallied for utility-sized wind and solar, and the weighted average of each state was calculated using equation 5. A sample calculation and the resultant of three states, New Mexico, Massachusetts, and Florida are shown below in Table 13. The top five lowest weighted LCOE averages are given below in Table 14, along with Figure 5 that shows the weighted average in each state.

$$(6)\ \text{Weighted average} = (LCOE_S * C_S) + (LCOE_W * C_W)$$

Table 13: Weighted average data and calculations of weighted average

State	**New Mexico**	**Massachusetts**	**Florida**
Solar LCOE ($LCOE_S$)	3.77 ¢/kWh	5.69 ¢/kWh	4.61 ¢/kWh
Wind LCOE ($LCOE_W$)	3.58 ¢/kWh	3.72 ¢/kWh	6.13 ¢/kWh
Installed solar capacity percent (C_S)	0.2890	0.8663	1.0000

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Installed solar capacity percent (C_W)	0.7110	0.1337	0.0000
Calculated weighted average	3.63 ¢/kWh	5.43 ¢/kWh	4.61 ¢/kWh

Table 14: Top 5 states weighted averages

State	**Weighted Average LCOE (¢/kWh)**	**Percent Difference from nation average**
SD	3.47	-20.51%
KS	3.49	-20.08%
TX	3.61	-17.29%
NM	3.63	-16.78%
ND	3.66	-16.20%

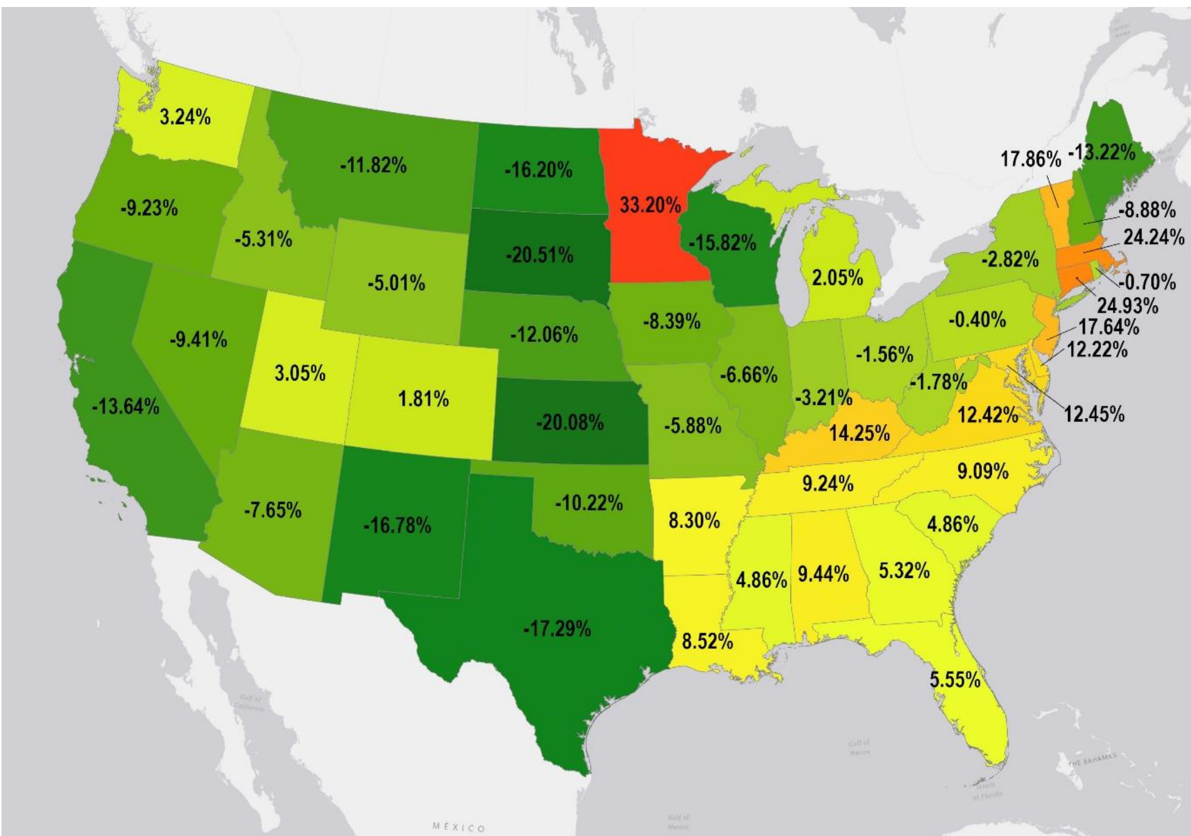

Figure 5: Percent differences from national average, using LCOE weighted average

7.4.3 Weighted vs. 50/50 Average Discussion

Only New Mexico and Kansas were in the top five lowest LCOE in both averaging methods. The LCOE weighted average was 7% lower for the U.S. than that of the 50/50 method. However, as mentioned earlier, wind energy is 17% cheaper than solar and is more prevalent historically. Therefore, states like

Kansas and the Dakotas top the list in a weighted average approach since wind is 99% of the installed renewable capacity. New Mexico current installed capacity is 29% solar and 71% wind. This is nearly identical to the U.S. overall installed capacity ratio at 28% solar and 72% wind.

8 Comparison to NREL and UC Berkeley LCOE estimates

System Advisor Model (SAM) simulations were performed on three potential solar sites throughout the continental U.S. to compare to LCOE values reported by NREL in its 2018 study [5]. The sites are as follows: Phoenix, Arizona; New York, New York; Joplin, Missouri. Each site was given identical technical parameters such as the solar module, inverter, array size, orientation, tracking, and wiring set-up.

After simulations were performed for each site, LCOE values were gathered and given below in Table 15 and Table 16. LCOE values provided by NREL are also given and a percent difference between the two are shown. In general, since our report is based on large-scale installation assumptions, it should be expected for LCOEs to be slightly lower. Wind was compared to a national average reported by NREL [6].

Table 15: KiloNewtons LCOE findings compared to NREL values

Solar Site	**NREL LCOE (¢/kWh)** [5]	**KiloNewton LCOE (¢/kWh)**	**% Difference**
Phoenix, AZ	4.1	3.93	-4.15%
New York, NY	5.7	5.50	-3.50%
Joplin, MO	5.2	4.97	-4.42%

Table 16: KiloNewtons U.S average of LCOE compared to NREL value

Wind Site	**NREL LCOE (¢/kWh)** [6]	**KiloNewton LCOE (¢/kWh)**	**% Difference**
U.S. average wind	4.2	4.17	-0.68%

A recent study by University of California, Berkeley has shown similar results as well using their own methodology, though they have projected the cost of energy farther out in 2035. New Mexico is shown in the lowest cost category in both wind and solar LCOE in Figure 6, as well as listed as the top solar capacity factor in the nation [15].

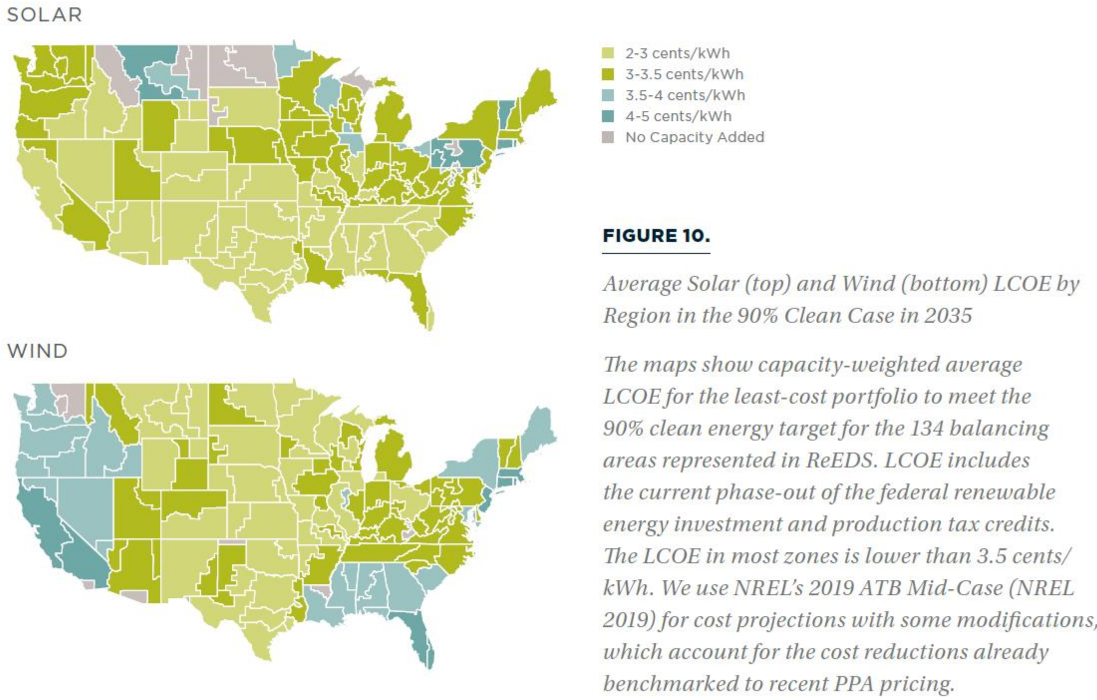

Figure 6: UC Berkeley figure showing 2035 LCOEs for the continental United States

9 Conclusion

Levelized Cost of Energy is an extremely helpful value when determining the overall financial feasibility of installing a power plant/farm in a region. While dependent primarily on variable wind and solar resources available, LCOE is dependent on many factors such as land, labor, and equipment costs.

The LCOE of wind, on average, was 17% cheaper than solar and on average, makes up the majority of current installed utility-scale farms, at 72% wind/ 28% solar nationwide. This trend both explains why wind power is more predominant than solar nationally, and why states that are predisposed toward wind power yield lower weighted average values for renewables. It is important to note that the weighted average method may not include any substantial mixture of power and can be 99-100% either wind or solar in extreme cases (such as the leading 3 states). **New Mexico is the fourth lowest LCOE using a weighted average approach at 3.63 ¢/kWh, 16.78% below the national average**. If the 99-100% wind states are excluded in this analysis, **New Mexico is the leading state in the continental United States for any meaningful mixture of wind and solar resources**.

In the future, for supplying more reliable power for typical loads on the grid, a more balanced mixture of both wind and solar is desirable, supplemented by energy storage, as forecasted by the 2035 UC Berkeley Study [15], among others. **New Mexico yields the lowest LCOE in the continental United States using a 50/50 mix of wind and solar at 3.68 ¢/kWh, 19.79% below the national average.**

New Mexico fared very well overall, along with Texas, the only two states appearing **consistently in the top 5 states for all PP and LCOE analyses KiloNewton conducted**.

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Appendix A. Sites Selected, by State

State	Solar Site (city)	Wind Site (city)
Alabama	Montgomery	Mentone
Arizona	Kingman	Tusayan
Arkansas	Fayetteville	Decatur
California	Barstow	Banning
Colorado	Alamosa	Allenspark
Connecticut	Lebanon	Clinton
Delaware	Georgetown	Long Neck
Florida	St. Petersburg	Homestead
Georgia	Georgia	Wilmington Island
Idaho	Shoshone	Mountain Home
Illinois	Lincoin	Sheldon
Indiana	Princeton	Goodland
Iowa	Sidney	Harris
Kansas	Johnson	Ensign
Kentucky	Mayfield	Uniontown
Louisiana	Shreveport	Cameron
Maine	Sanford	Eastport
Maryland	Eastville	Mountain Lake Park
Massachusetts	Franklin	Chatham
Michigan	Kalamazoo	Port Austin
Minnesota	Luverne	Jeffers
Mississippi	Clinton	Tunica
Missouri	Joplin	London
Montana	Broadus	Ekalaka
Nebraska	Benkelman	Harrisburg
Nevada	Searchlight	Serchlight
New Hampshire	Hollis	Nelson
New Jersey	Buena Vista Township	Stone Harbor
New Mexico	Deming	Vaughn
New York	Brooklyn	Ellenburg
North Carolina	Charlotte	Sugar Mountain
North Dakota	Bowman	Kulm
Ohio	Georgetown	Marblehaed
Oklahoma	Boise City	Hardesty
Oregon	Bend	Wasco
Pennsylvania	Shrewsbury	Erie
Rhode Island	Richmond	Galilee
South Carolina	Ridgeland	Georgetown

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South Dakota	Pine Ridge	Goodwin
Tennessee	Memphis	Munford
Texas	Horizon City	Perryton
Utah	St.George	Monticello
Vermont	Springfield	Stannard
Virginia	Stuart	White Stone
Washington	Golden Dale	Fairfield
West Virginia	White Sulphur Springs	Hambleton
Wisconsin	Platteville	Algoma
Wyoming	Riverton	Rock River

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Appendix B. Site Specific Variables

State	Wind PP MWh	Solar PP Mwh	Land cost $/year	Income tax	Sales tax	Wind LCOE ¢/kWh	Solar LCOE ¢/kWh	50/50 Avg. LCOE	Wgt. Avg. LCOE	Solar cost of labor $/Wdc	Wind BOS cost ($/kW)	Wind Icing	Solar Soiling	Region
AL	274286	204042	$ 5,020	5.00%	5.14%	4.32	4.78	4.55	4.78	$ 0.08	316.12	0.5%	2.000%	SE
AR	348460	200666	$ 7,799	6.60%	2.93%	3.46	4.73	4.10	4.73	$ 0.07	309.47	0.5%	2.000%	Delta
AZ	228302	249763	$ 2,151	4.50%	2.77%	5.14	3.89	4.52	4.03	$ 0.09	326.09	2.0%	2.000%	Mountain
CA	302559	256116	$ 8,629	13.30%	1.31%	3.84	3.73	3.79	3.77	$ 0.12	353.86	0.0%	2.000%	Pacific
CO	233257	228090	$ 2,661	4.63%	4.73%	4.49	4.2	4.35	4.45	$ 0.09	326.70	2.0%	7.947%	Mountain
CT	299696	176999	$ 21,358	6.99%	0.00%	4.02	5.54	4.78	5.46	$ 0.13	357.89	2.0%	5.384%	NE
DE	304846	191635	$ 21,358	6.60%	0.00%	3.92	4.96	4.44	4.90	$ 0.09	326.09	0.5%	2.665%	NE
FL	193683	224284	$ 10,389	0.00%	1.05%	6.13	4.61	5.37	4.61	$ 0.08	316.07	0.0%	2.000%	SE
GA	261925	210031	$ 7,229	5.75%	3.29%	4.48	4.6	4.54	4.60	$ 0.08	316.17	0.0%	2.000%	SE
IA	337018	190112	$ 18,671	8.53%	0.82%	4	4.99	4.50	4.00	$ 0.10	328.53	2.5%	5.490%	Corn
ID	301856	186834	$ 4,913	6.93%	0.03%	3.93	4.97	4.45	4.14	$ 0.09	318.51	2.0%	15.000%	Mountain
IL	301856	178316	$ 21,760	4.95%	2.49%	4.06	5.75	4.91	4.08	$ 0.15	378.21	2.0%	4.494%	Corn
IN	295024	187641	$ 16,818	3.23%	0.00%	4.11	5.31	4.71	4.23	$ 0.10	333.21	2.0%	2.720%	Corn
KS	348662	217232	$ 11,225	5.70%	2.17%	3.49	4.51	4.00	3.49	$ 0.09	322.91	1.0%	3.620%	N. Plains
KY	274243	193120	$ 7,586	5.00%	0.00%	4.33	4.99	4.66	4.99	$ 0.10	327.97	0.5%	2.751%	Appal
LA	266622	206150	$ 8,456	6.00%	5.00%	4.42	4.74	4.58	4.74	$ 0.09	322.25	0.0%	2.000%	Delta
MA	331312	172965	$ 21,358	5.00%	0.00%	3.72	5.69	4.71	5.43	$ 0.14	367.02	1.0%	7.235%	NE
MD	284857	179324	$ 21,260	5.75%	0.00%	4.17	5.31	4.74	4.91	$ 0.09	322.72	2.0%	6.647%	NE
ME	315264	173523	$ 21,358	7.15%	0.00%	3.78	5.42	4.60	3.79	$ 0.09	319.96	3.0%	7.386%	NE
MI	311727	170089	$ 15,792	4.25%	0.00%	4.39	5.65	5.02	4.46	$ 0.10	333.68	3.0%	6.496%	Lake
MN	296656	176146	$ 10,365	9.85%	0.55%	5.9	5.43	5.67	5.82	$ 0.13	357.33	3.0%	8.754%	Lake
MO	300264	199676	$ 13,592	5.40%	3.90%	4.03	4.97	4.50	4.11	$ 0.12	351.71	0.5%	2.564%	Corn
MS	273350	207652	$ 7,261	5.00%	0.07%	4.32	4.58	4.45	4.58	$ 0.08	312.00	0.5%	2.000%	Delta
MT	313852	186012	$ 2,142	6.90%	0.00%	3.82	5.13	4.48	3.85	$ 0.10	331.24	3.0%	5.800%	Mountain
NC	310109	199096	$ 12,042	5.25%	2.22%	3.89	4.81	4.35	4.76	$ 0.08	312.23	1.5%	2.000%	Appal
ND	337057	183740	$ 6,622	2.90%	1.85%	3.66	5.36	4.51	3.66	$ 0.10	335.55	4.0%	7.492%	N. Plains
NE	311034	207538	$ 8,480	6.84%	1.35%	3.83	4.64	4.24	3.84	$ 0.09	323.80	2.0%	5.592%	N. Plains
NH	303267	173834	$ 21,358	5.00%	0.00%	3.98	5.51	4.75	3.98	$ 0.10	333.87	3.0%	7.128%	NE
NJ	286882	185895	$ 43,827	10.75%	0.00%	4.11	5.15	4.63	5.14	$ 0.14	369.73	0.5%	2.889%	NE
NM	338988	257481	$ 1,313	4.90%	2.69%	3.58	3.77	3.68	3.63	$ 0.08	316.59	1.0%	2.000%	Mountain
NV	304935	252165	$ 2,151	0.00%	1.29%	4.04	3.95	4.00	3.96	$ 0.09	327.12	0.0%	2.000%	Mountain
NY	239502	184718	$ 5,004	8.82%	4.49%	4.06	5.5	4.78	4.24	$ 0.14	363.60	3.0%	2.480%	NE
OH	292842	180695	$ 22,996	4.80%	1.42%	4.13	5.39	4.76	4.30	$ 0.12	345.99	0.5%	3.249%	Corn
OK	304908	230736	$ 2,948	5.00%	4.42%	3.92	4.16	4.04	3.92	$ 0.08	315.18	1.0%	4.085%	S. Plains
OR	302936	199256	$ 2,150	9.90%	0.00%	3.89	4.73	4.31	3.96	$ 0.11	340.05	0.5%	6.152%	Pacific
PA	281768	178175	$ 10,761	3.07%	0.34%	4.3	5.5	4.90	4.35	$ 0.11	340.05	2.0%	7.277%	NE
RI	325660	181686	$ 21,358	5.99%	0.00%	3.75	5.34	4.55	4.34	$ 0.13	356.72	1.0%	2.000%	NE
SC	257862	207063	$ 6,280	7.00%	1.43%	4.52	4.58	4.55	4.58	$ 0.08	317.76	0.0%	2.000%	SE
SD	359464	193395	$ 8,480	0.00%	1.90%	3.47	5.14	4.31	3.47	$ 0.08	314.06	4.0%	8.435%	N. Plains
TN	288429	200404	$ 9,664	1.00%	2.47%	4.22	4.86	4.54	4.77	$ 0.08	317.53	0.5%	2.230%	Appal
TX	347768	257614	$ 3,351	0.00%	1.94%	3.59	3.86	3.73	3.61	$ 0.08	318.42	0.5%	2.000%	S. Plains
UT	212431	238509	$ 3,905	4.95%	0.99%	5.47	4.06	4.77	4.50	$ 0.09	324.97	2.0%	2.280%	Mountain
VA	264238	192277	$ 10,064	5.75%	0.35%	4.45	4.91	4.68	4.91	$ 0.08	315.42	0.5%	2.347%	Appal
VT	249324	161403	$ 21,358	8.75%	0.18%	4.63	5.76	5.20	5.15	$ 0.09	327.22	4.0%	11.070%	NE
WA	275232	137716	$ 2,196	0.00%	2.67%	4.49	7.47	5.98	4.51	$ 0.12	354.28	2.0%	3.141%	Pacific
WI	335861	168628	$ 14,085	7.65%	0.44%	3.6	5.76	4.68	3.68	$ 0.11	342.06	2.5%	8.305%	Lake
WV	274258	165414	$ 5,307	6.50%	0.39%	4.29	5.8	5.05	4.29	$ 0.09	322.21	1.0%	3.038%	Appal
WY	248510	199446	$ 1,811	0.00%	1.36%	4.09	5.1	4.60	4.15	$ 0.09	325.86	3.0%	5.879%	Mountain

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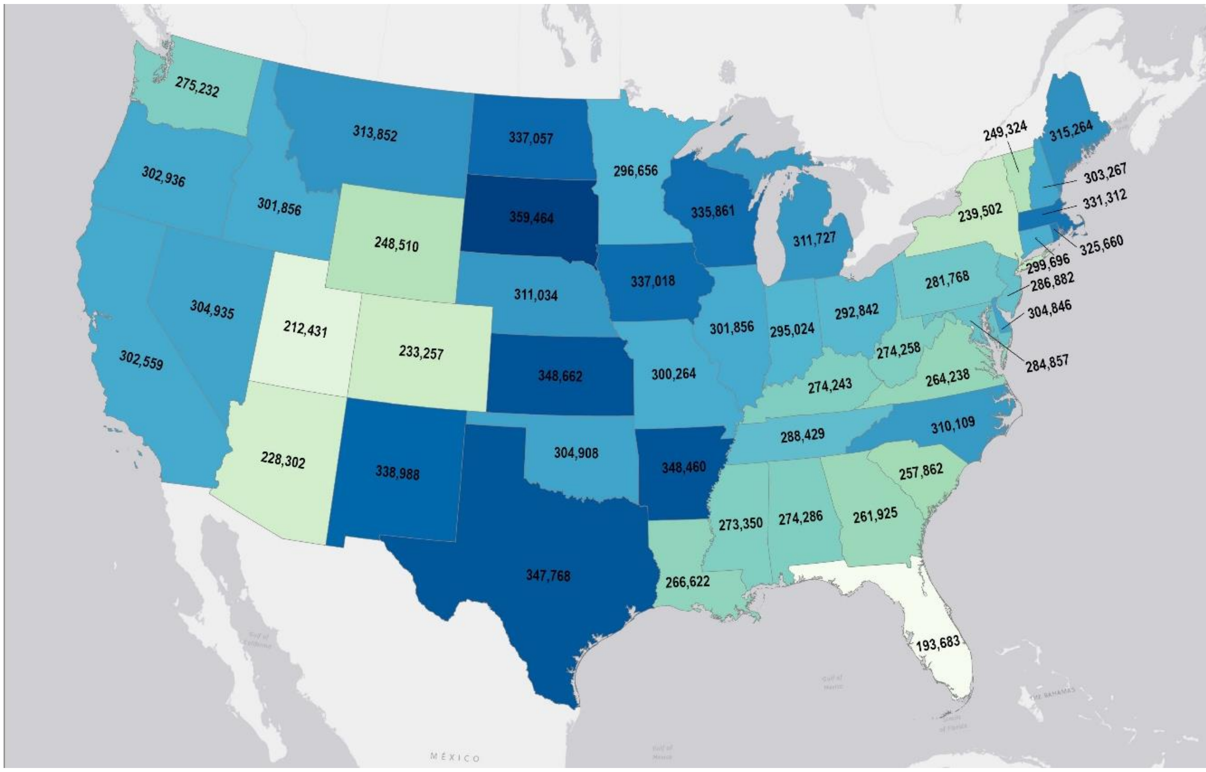
Appendix C. U.S. Lower 48 Map of Wind Power Production



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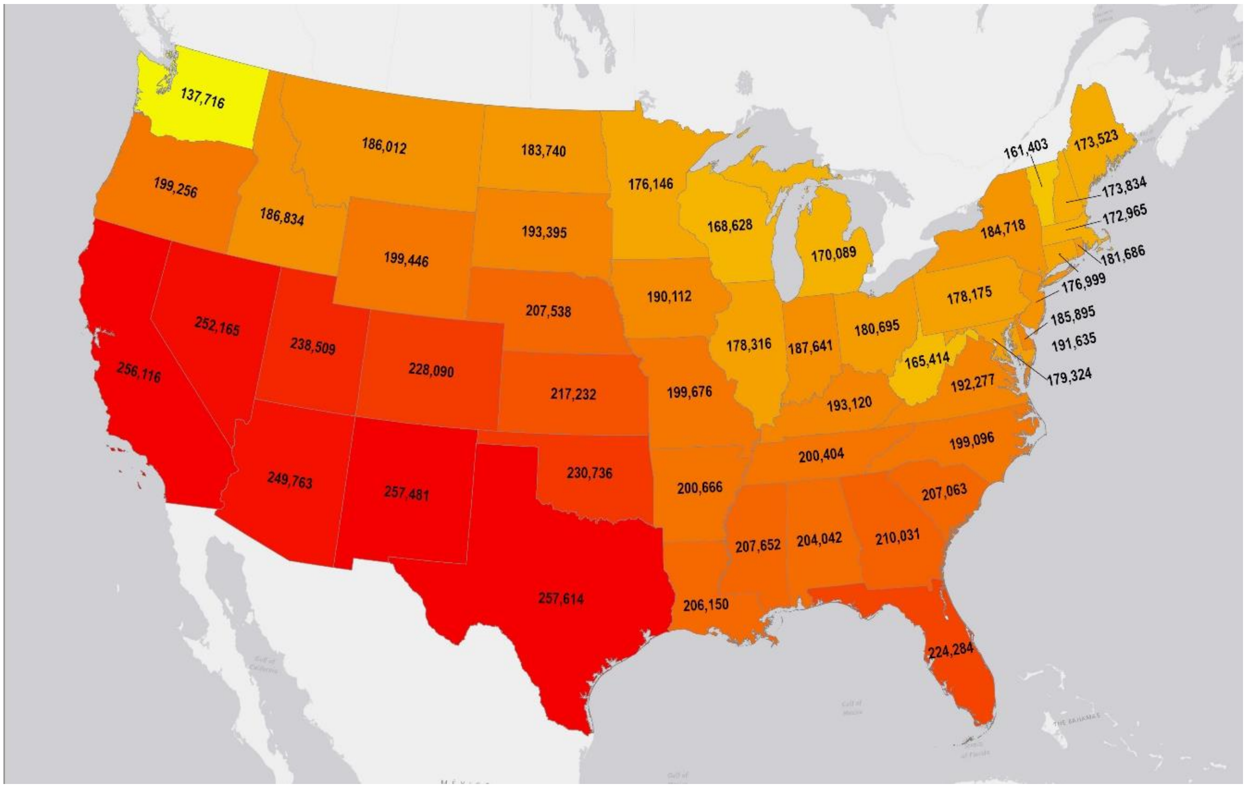
Appendix D.U.S. Lower 48 Map of Solar Power Production



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