

# Power to Memphis: Renewable and Storage Supplement

## PREPARED FOR

Friends of the Earth

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## Notice

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# I. Executive Summary

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This short supplementary report provides additional background related to our January 2019 report entitled “Power to Memphis: Options for a Reliable, Affordable and Greener Future.” More specifically, it provides more detail on the assumptions made concerning the cost of renewable energy and storage options in the report and compares those to more recent real world evidence related to the cost of various renewable and battery storage options that Memphis could make an important part of a future supply portfolio to meet its electricity demand.

The supplemental information provided shows that the assumptions made in the January report are reasonable and, given recently observed costs for wind, solar and battery resources, potentially on the conservative side. This means that the costs that Memphis would likely incur if it developed a substantial portfolio of renewable resources as part of a 2024 supply mix could be lower than assumed in the January report, which confirms and strengthens our conclusion that the average cost of electricity generating portfolios that would supply Memphis with up to a third of its total electricity demand<sup>1</sup> in 2024 from renewable resources would likely have an average cost below the current TVA rate.

If, in addition, MLGW can take advantage of its access to tax-advantaged financing, its cost of developing and owning solar and wind resources would potentially be even more advantageous relative to the costs assumed in the January 2019 report. While the local potential for solar development far exceeds the levels of deployment assumed in the report for 2024, reaching the level of 350 MW assumed in our January 2019 report will require a determined effort to scale up deployment between now and then. Given that it is likely that there remain important opportunities in Memphis to improve energy efficiency cost effectively, emphasizing energy efficiency efforts going forward would not only help lower Memphis customers’ electricity bills today, it would also make it easier to meet its own (relatively lower) electricity demand by 2024 and thereafter.

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<sup>1</sup> Because renewable energy sources such as wind and solar PV can only produce electricity when the wind is blowing and the sun is shining whereas traditional power plants can produce power when needed, the amount of solar and wind capacity (the number of wind turbines and solar panels) needed to produce 30% of Memphis electricity demand is higher than the conventional power generation capacity it would substitute for.

## II. Introduction

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In January 2019, The Brattle Group released a report (“The Brattle Report”), commissioned by Friends of the Earth, exploring the economics and reliability of various affordable and sustainable alternatives to Memphis, Light, Gas, and Water’s (“MLGW”) current energy supply from the Tennessee Valley Authority (“TVA”).<sup>2</sup> Friends of the Earth asked The Brattle Group to supplement the Brattle Report with additional background related to the assumptions and methodology underlying the short- and medium- term estimates of the cost of developing renewables and storage, as presented in that report. This supplement also compares those cost estimates to recent market experience as a benchmark of the reliability of those cost estimates.

## III. Derivation of Cost Estimates for Renewable and Storage Resources

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The renewable cost estimates we provide in our January 2019 report used a standard financial model developed by The Brattle Group and relied in large part on the 2018 Annual Technology Baseline Report (“ATB”) produced by the National Renewable Energy Labs (NREL)<sup>3</sup> as well as NREL’s “Wind Integration Data Set” and “Solar Integration Data Set.”<sup>4</sup>

The ATB projects capacity factors, overnight costs, and fixed operations and maintenance (“O&M”) costs to 2050 for both wind and solar projects for a variety of resource quality levels. For each such technology and resource level, the ATB presents three different cases: a “Low” (most optimistic) case, a “Mid” case, and a “Constant” case (which essentially assumes no technological progress beyond 2017). The analysis in the January 2019 report relied on the projections from the ATB “Mid” case as inputs for the factors listed above, as well as for the resource’s operating life.

Information for various locations in NREL’s “Wind Integration Data Set” and “Solar Integration Data Set” were the basis for the development of hourly renewable generation profiles for solar and wind. The selected generation profiles were used as inputs in production simulations carried out using PSO (Power Systems Optimizer), a state-of-the-art production cost simulation tool

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<sup>2</sup> Jurgen Weiss, Judy Chang, Nicholas Powers, and Kai Van Horn. “Power to Memphis: Options for a Reliable, Affordable, and Greener Future.” January 2019 (“The Brattle Report”).

<sup>3</sup> See <https://atb.nrel.gov/electricity/2018/>.

<sup>4</sup> See <https://www.nrel.gov/grid/wind-integration-data.html> and <https://www.nrel.gov/grid/solar-integration-data.html>.

developed by Polaris Systems Optimization, Inc. The modeling resulted in estimates of total annual electricity generation (MWh) for the assumed wind, solar, and storage resources.

For the financial model, the analysis in the January 2019 report assumed that all resources would be financed with a debt fraction of 50%, an interest rate on debt of 4.0%, and a return on equity of 10%. Combining Tennessee’s state tax rate of 6% with the federal tax rate of 21% yields the tax rate of 25.74% used in the model. The model uses tax depreciation schedules according to the IRS published recovery periods by class;<sup>5</sup> Solar, wind, and storage all were assumed to use a 5-year modified accelerated cost recovery system (“MACRS”).

As discussed in our initial report, Memphis’ status as a tax-exempt municipal borrower can provide access to tax-advantaged financing not available to most developers of renewables or storage projects. The January 2019 report demonstrated how, under certain assumptions, this could substantially lower the average cost of energy – also known as the levelized cost of energy (“LCOE”) – of the modeled resources.

## A. Wind

### 1. Brattle Assumptions

There is variation in the quality of the wind resources that would likely be available to MLGW in pursuing a high-renewables strategy. The Brattle analysis relies on NREL’s Wind Integration Data Set to identify wind generation profiles that are representative of wind resources in three potential locations: Memphis, Eastern Tennessee, and South Dakota.

The NREL ATB projections for capacity factors, overnight costs, and fixed O&M costs also vary based on the quality of the wind resource.<sup>6</sup> NREL ATB divides U.S. wind resources into ten distinct techno-resource groups (“TRGs”), based on wind speeds (where TRG 1 has highest wind speeds and TRG 10 has lowest wind speeds) as shown in Figure 1 below. NREL data from the Wind Integration Dataset on the capacity factors of current wind projects in or near the locations in question guided the assignment of the locations listed above to appropriate techno-resource groups. This in turn allows for the estimation of costs by assumed location.

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<sup>5</sup> See <https://www.irs.gov/pub/irs-pdf/p946.pdf>, Table B-2.

<sup>6</sup> The quality of the wind resource has a direct effect on capacity factor but also may mean that the optimal turbine technology can differ by location, leading to different assumptions regarding costs.

**Figure 1: NREL ATB Land-Based Wind Techno-Resource Groups**

Techno-Resource Group (TRG)	Wind Speed Range (m/s)	Weighted Average Wind Speed (m/s)	Weighted Average CAPEX (\$/kW)	Weighted Average OPEX (\$/kW/yr)	Weighted Average Net CF (%)	Potential Wind Plant Capacity (GW)	Potential Wind Plant Energy (TWh)
TRG1	8.2 - 13.5	8.7	1573	51	47.4%	100	414
TRG2	8.0 - 10.9	8.4	1592	51	46.2%	200	810
TRG3	7.7 - 11.1	8.2	1599	51	45.0%	400	1576
TRG4	7.5 - 13.1	7.9	1605	51	43.5%	800	3050
TRG5	6.9 - 11.1	7.5	1616	51	40.7%	1600	5708
TRG6	6.1 - 9.4	6.9	1642	51	36.4%	1600	5098
TRG7	5.4 - 8.3	6.2	1678	51	30.8%	1600	4320
TRG8	4.7 - 6.9	5.5	1708	51	24.6%	1600	3443
TRG9	4.0 - 6.0	4.8	1713	51	18.3%	1600	2558
TRG10	1.0 - 5.3	4.0	1713	51	11.1%	1148	1116
Total						10,648	28,092

Source: NREL ATB 2018.

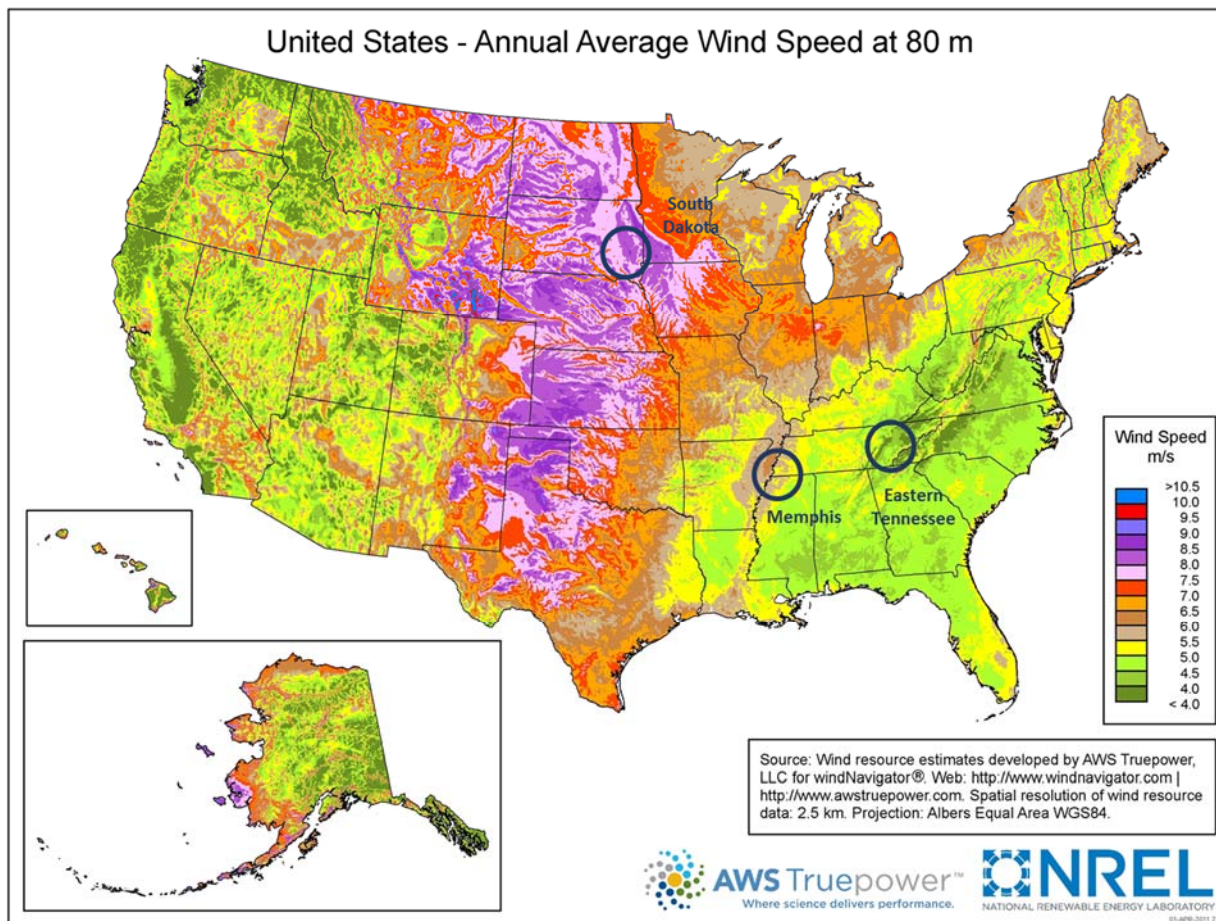
Using the information from NREL’s Wind Maps shown in Figure 2, which identify zones of comparable wind speeds across the U.S. by color, the three wind regions in our model were mapped to appropriate TRGs to estimated wind speeds:<sup>7</sup>

- Memphis: TRG 7
- Eastern Tennessee: TRG 6
- South Dakota: TRG 3

These resource locations are indicated by a circle in Figure 2.

<sup>7</sup> See <https://sam.nrel.gov/> and <https://www.nrel.gov/gis/wind.html>.

Figure 2: US Wind Speed Map



Sources and Notes:

NREL map ([https://www.nrel.gov/gis/images/80m\\_wind/USwind300dpe4-11.jpg](https://www.nrel.gov/gis/images/80m_wind/USwind300dpe4-11.jpg)) modified by The Brattle Group.

The map in Figure 2 indicates that the wind resources in Memphis are among the best in the Southeastern United States. The map also illustrates that most of the best wind resources in the country are located in the central corridor from North Dakota south through Texas. Memphis' proximity to the MISO region and the Southwest Power Pool ("SPP"), which together encompass much of this wind-rich region, means that Memphis should be able to leverage some of the very low-cost wind in those regions. The analysis in the 2019 report used a representative location in eastern South Dakota (within MISO), as indicated in the map, to evaluate the economics of "imported" wind. In the near term (including by 2024), the amount of wind that can be sourced from these wind-rich regions may be limited by existing transmission capacity to these areas, which is why we assumed that a 2024 portfolio of resources would need to rely on some more "local" wind. However, over time additional transmission could be added to provide Memphis access to larger amounts of some of the best wind resources in the world.



## 2. Benchmark against Other Sources

Data on historical power purchase agreements (“PPAs”) for wind projects demonstrate that the cost estimates contained in the January 2019 Brattle report are reasonable, and may even overestimate the likely cost of developing wind resources to serve MLGW load. The top panel of Figure 3 below shows PPA prices of a wide variety of wind projects over the last 23 years, as compiled by Lawrence Berkeley National Laboratory (“LBNL”) for the US Department of Energy (“DOE”). The bottom panel focuses on the last four years and highlights the single wind PPA from the Southeastern United States that is included in the LBNL database.

**Figure 3: US Wind PPA Prices, 1996-2018**



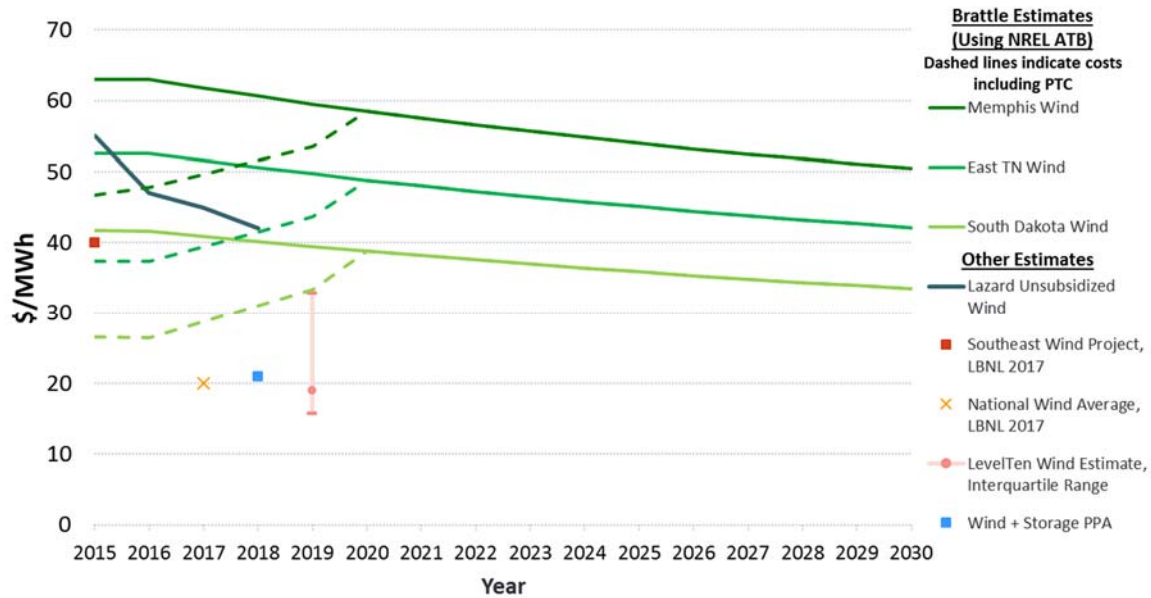
**Sources and Notes:**

LBNL, <https://emp.lbl.gov/wind-power-purchase-agreement-ppa-prices>.

Size of circle reflects size of wind project.

Figure 4 compares Brattle’s costs estimates using NREL ATB with recent reports and publicly available data on signed wind PPAs.<sup>8</sup> Our financial model did not include the Renewable Electricity Production Tax Credit ("PTC") for wind, because it the credit is currently scheduled to be phased out before 2024, which was the basis for our earliest scenarios.<sup>9</sup> However, its effect on LCOE estimates is reflected in Figure 4 below, as any wind project that has commenced construction before the end of 2019 will be able to leverage it.<sup>10</sup>

**Figure 4: Wind Costs Compared to Brattle Estimates**



Sources and Notes: NREL ATB 2018; Lazard (<https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2018/>); LBNL 2017 Wind Technologies Market Report ([https://emp.lbl.gov/sites/default/files/2017\\_wind\\_technologies\\_market\\_report.pdf](https://emp.lbl.gov/sites/default/files/2017_wind_technologies_market_report.pdf)) and (<https://emp.lbl.gov/wind-power-purchase-agreement-ppa-prices>); LevelTen Energy PPA Price Index, Q1 2019 (<https://leveltenenergy.com/blog/ppa-price-index/q1-2019/>).

For Brattle estimates, dashed line indicates LCOE when accounting for Production Tax Credits. The 2015 values use the NREL ATB 2017, all other years use the NREL ATB 2018.

The wind plus storage PPA is the median bid price for Xcel Energy’s Colorado utility subsidiary’s December 2017 solicitation (see [https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery\\_storage.pdf](https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf)).

<sup>8</sup> While the execution of renewable PPAs is tracked by multiple trade press outlets, the price of the PPA is typically not made public.

<sup>9</sup> For more information on the PTC, see <https://www.energy.gov/savings/renewable-electricity-production-tax-credit-ptc>.

<sup>10</sup> Determination of whether a project has commenced construction requires that a project has begun “physical work of a significant nature” or that a minimum of 5% of the total cost of the facility has been incurred. See <https://www.energy.gov/savings/renewable-electricity-production-tax-credit-ptc>.

Several key takeaways emerge from this comparison:

- Brattle’s estimates appear conservative compared to the other sources, partially because our estimates did not include the PTC for wind. The dashed lines in Figure 4 indicate the predictions from our LCOE methodology once the PTC is taken into account. These projections are much more in line with recent reports and PPAs.
- An example is provided by a recent wind PPA for a project in the Southeast, executed in 2015 at an approximate PPA price of \$40/MWh. Incorporating the PTC into the Brattle LCOE methodology, and casting it back to 2015 suggests that the methodology used in the January report is reasonable, as the \$40/MWh estimate falls between the dashed lines for East Tennessee and Memphis wind.
- Data from more recent PPAs shows that they are consistently priced around \$20/MWh, well below rates included in Brattle’s earlier report. However, given their timing, these wind projects will take advantage of the full production tax credit (PTC), which is currently being phased out, and furthermore, likely include some of the best wind resources in the country.
- The PTC has a large impact on costs, such that the tax advantages from commencing construction this year outweigh the effects of several years of cost decreases as projected under the NREL ATB “Mid” scenario. Wind projects started before the end of 2019 will be able to lock in the \$20/MWh (2¢/kWh) PPA price described above, which is roughly half the LCOE for imported wind used in the January 2019 report. However, even without the PTC, local wind would have an average cost under \$60/MWh (6¢/kWh) today. Estimates of the cost of South Dakota wind without the PTC are below \$40/MWh today, decreasing to approximately \$33/MWh by 2030.
- While LCOE for a single resource is not directly comparable to a full-requirements rate, it is worth noting that these estimates are all well below the rate of roughly \$75/MWh (7.5¢/kWh) charged by MLGW’s current full requirements provider, TVA. As presented in the January 2019 Report, representative portfolios with significant renewables penetration can be used to meet Memphis’ needs by 2024 at a cost of 23% to 32% below the current TVA rate. The benchmark analysis here indicates that the actual cost of wind resources will likely be comparable or lower than was assumed in the analysis underlying that report.

## B. Solar Photovoltaic

### 1. Brattle Assumptions

Solar photovoltaic (“PV”) resources used in the report include utility scale solar, distributed commercial solar, and distributed residential solar. The analysis underlying the January 2019 Brattle Report assumed a useful life of 30 years for all solar resources, consistent with the assumptions in the NREL ATB.

The investment tax credit (“ITC”) for solar is currently 30%, falling gradually to a 10% rate, which will take effect on January 1, 2022. The Brattle analysis assumed that that 10% rate would remain in effect through December 31, 2029, falling to 0% thereafter.<sup>11</sup>

The Brattle analysis included solar capacity at two representative locations, relying on solar generation profile data from NREL’s “Solar Integration Data Set.” Data from existing solar installations near Memphis represent potential local solar resources, while Northwest Texas is used to represent remote higher-quality solar resources.

NREL ATB provides solar capacity factors for five proxy locations: Seattle, Chicago, Kansas City, Los Angeles, and Daggett, CA.<sup>12</sup> Using solar irradiance maps provided by NREL, it is possible to assign Memphis and Northwest Texas solar resources to the proxy locations most comparable in terms of the quality of the solar resource.<sup>13</sup> Memphis and Northwest Texas were assigned to Kansas City and Los Angeles proxy locations, respectively. Figure 5 below shows solar irradiance maps and how they compare to the proxy locations used in the report.

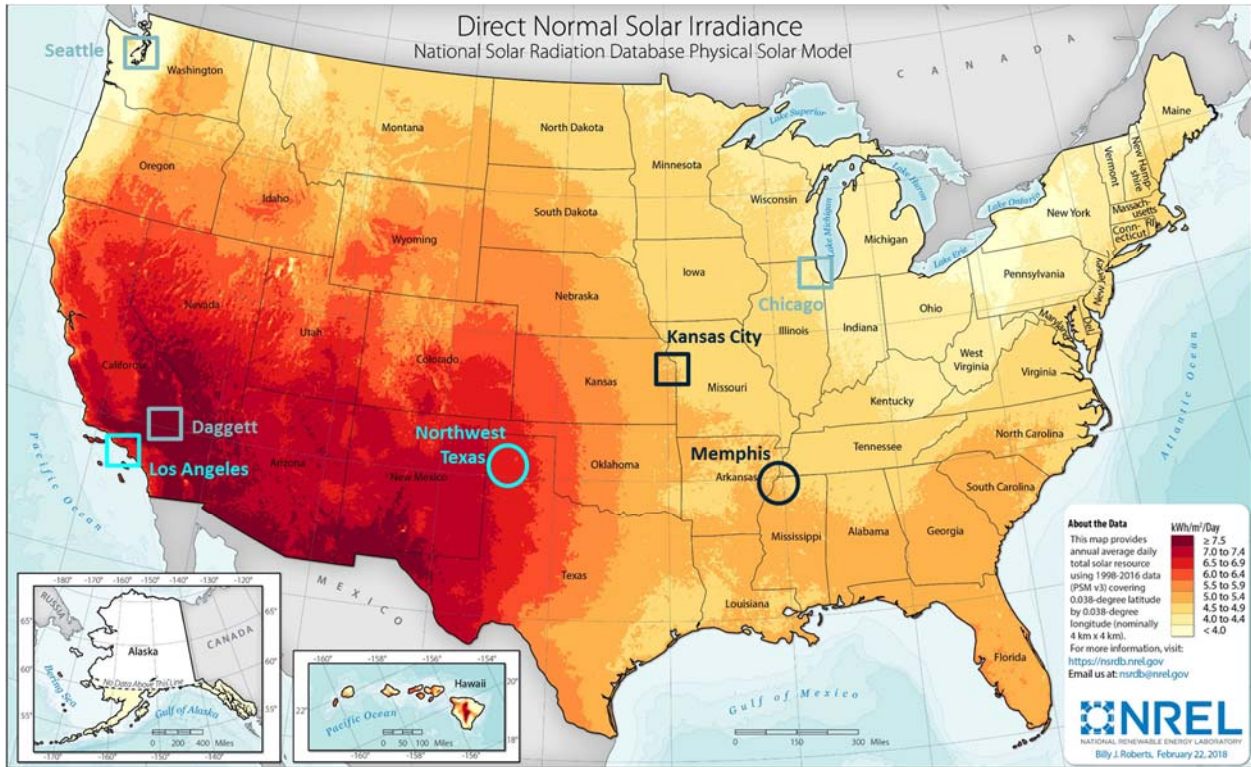
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<sup>11</sup> Unlike the PTC, the development must be operational in the year in which the first credit is taken. The ITC will drop to 26% in 2020 and to 22% in 2021, For more information on the ITC, see <https://www.energy.gov/savings/business-energy-investment-tax-credit-itc>. Note that the ITC for residential solar PV will be entirely phased out under current regulations.

<sup>12</sup> In contrast to their wind projections, NREL ATB’s projections for overnight solar costs and fixed O&M costs do not vary by location.

<sup>13</sup> See <https://www.nrel.gov/gis/solar.html>.

**Figure 5: US Solar Irradiance Map**



**Sources and Notes:**

NREL map ([https://www.nrel.gov/gis/assets/pdfs/solar\\_dni\\_2018\\_01.pdf](https://www.nrel.gov/gis/assets/pdfs/solar_dni_2018_01.pdf)) modified by The Brattle Group. Squares denote NREL ATB proxy location. Circles denote Brattle report resource location. As the color coding indicates, Memphis was matched to the Kansas City profile, while Northwest Texas was matched to the Los Angeles profile.

Figure 5 indicates that Memphis has solar resources that are similar to some of the better solar regions in the southeastern United States. Furthermore, Memphis’ solar resources are equal or better than those of several states with well-developed solar capacity, such as North Carolina, New Jersey, and Massachusetts. Also, conditional on the availability of transmission capacity, Memphis could have access to extremely solar-rich regions. The analysis underlying the January 2019 report used Northwest Texas (in SPP) as a representative location to analyze the comparative economics of “imported” solar power.

*a. Utility Scale Solar*

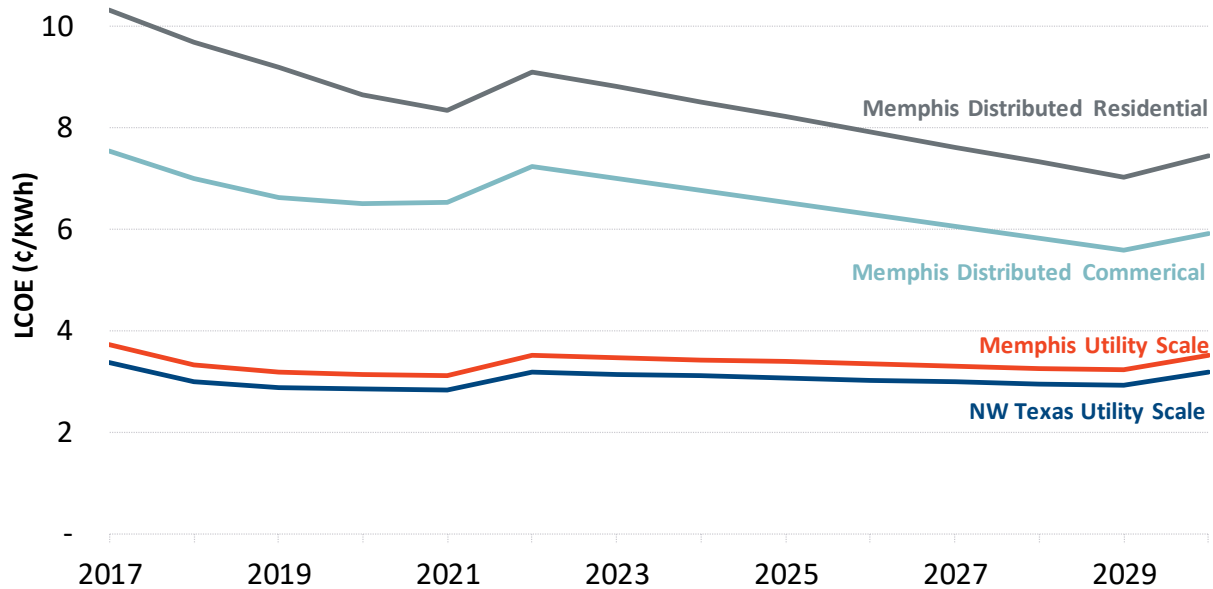
NREL ATB provides different values of the relevant projection parameters, according to the site of the PV installation – utility scale, distributed commercial, or distributed residential. Utility scale solar resources were assigned capacity factors, overnight costs, and fixed O&M from NREL ATB “Solar Utility PV Inputs.”

*b. Distributed Solar*

For distributed solar the analysis underlying the January Report assumed that all distributed solar resources would be sited in Memphis, relying on the NREL ATB inputs (capacity factors, overnight

costs, and fixed O&M) for Kansas City, the closest comparable location included in the dataset. When used in the Brattle model, those inputs generally produce substantially lower LCOE estimates for distributed commercial than for distributed residential, as demonstrated in Figure 6.

**Figure 6: Solar PV LCOE Projections Through 2030**



All scenarios assumed 250 MW, split evenly between residential and commercial locations) by 2024. Estimating solar capacity potential for Memphis and Shelby County over recent years confirmed the feasibility of this assumption.

We first estimated Memphis’ long-term rooftop potential. A 2016 NREL report on rooftop solar potential provides an estimate of Tennessee’s statewide rooftop solar PV potential.<sup>14</sup> Calculating the potential per population for Tennessee and scaling it to Shelby County and to the City of Memphis results in an estimated 2.37 to 3.40 GW of rooftop solar in Shelby County. Assuming that a typically sized rooftop solar array has a capacity of 5 kW,<sup>15</sup> this represents approximately 500,000 solar roofs or 10-15 times the 250 MW we assumed could be developed by 2024. Table 1 presents these calculations.

<sup>14</sup> NREL, "Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment", January 2016.

<sup>15</sup> Such an array would produce a little less electricity than a typical household consumes.

**Table 1: Estimated Rooftop Solar PV Potential in Shelby County and Memphis**

			Tennessee	Shelby County	City of Memphis
			[1]	[2]	[3]
Population	#	[a]	6,715,984	936,961	652,236
Land Area	sq miles	[b]	41,235	763	315
Installed Capacity Potential	GW	[c]	24.40		
Prorated by Population	GW	[d]		3.40	2.37

*Sources and Notes:*

[a]: US Census July 2017 estimates.

[b]: US Census July 2017 estimates.

[1c]: NREL, "Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment", January 2016, Table 6.

[2d]: [1c] x ([2a] / [1a])

[3d]: [1c] x ([3a] / [1a])

[3e]: [1c] x ([2b] / [1b])

[3e]: [1c] x ([3b] / [1b])

The NREL report also presents the technical potential of rooftop PV for various cities throughout the country. While Memphis is not among those cities, three geographically proximate though smaller cities (Little Rock, Arkansas; Birmingham, Alabama; and St. Louis, Missouri) are included. Scaling up the rooftop PV potential for each those cities to account for Memphis’ larger population generates results that are consistent with our estimates using the Tennessee data. These results are presented in Table 2. The Department of Energy also estimates Memphis’ Rooftop PV potential at 1,439 MW (1.4 GW) – or roughly 250,000 solar roofs, using only small buildings, and using only the city of Memphis, as opposed to Shelby County as a whole.<sup>16</sup>

These various sources and methods all produce rough estimates of Memphis’ long-term rooftop solar PV potential that far exceed the 250MW assumed in the 2024 scenarios of the January 2019 Report. Simply put, rooftop space will not be a limiting factor in achieving the solar penetration levels assumed to be built by 2024 and presented in the January 2019 report.

<sup>16</sup> Department of Energy, “State & Local Energy Data.” <https://www.eere.energy.gov/sled>. The Department of Energy estimates that Memphis has 171,700 suitable small buildings. The estimated energy generation potential (1.9 GWh per year) implies a capacity factor of 15.1%, which is in line with the NREL ATB-based assumption used for distributed commercial-sited solar PV installations (15.6%) and distributed residential-sited solar PV installations (16.6%).

**Table 2: Estimated Rooftop Solar PV Potential for Memphis: Alternate Approach**

		Little Rock, AR	Birmingham, AL	St. Louis, MO
Rooftop Solar Capacity Potential (GW)	[1]	0.8	0.9	1.5
July 1, 2018 Population Estimate	[2]	198,606	210,710	308,626
GW per 100,000 residents	[3]	0.40	0.43	0.49
Implied Memphis Potential (GW)	[4]	2.6	2.8	3.2

*Sources and Notes:*

[1]: NREL, "Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment", January 2016, Table 2.

[2]: US Census July 2017 estimates.

[3]: [1] x 10<sup>5</sup> / [2]

[4]: [3] x July 1, 2017 population of Memphis (652,236).

*c. Pace of Solar Build-Out*

In total, the 2024 scenarios presented in the January report assumed that 100 MW of local utility-scale solar and 250 MW of local distributed solar (350 MW total) could be online by 2024. It is important not just to consider the economics of both types of solar PV and the long-term technical rooftop potential, but also the pace that would be needed to install 350 MW of distributed solar by 2024. Publically-available information can be used to provide benchmarks for the amount of solar capacity that can realistically be added in a year in a city of Memphis' size. Specifically, Environment America publishes an annual report that lists the top 20 cities by solar PV capacity. A comparison of the 2017 and 2018 reports provides insight into the pace of rooftop solar development in various locations.<sup>18</sup>

Table 3 below shows increases in solar PV capacity per capita, and scales those additions to Memphis' population.



**Table 3: Installed Solar Capacity by City for 2016 and 2017, Leading Cities**

	Per Capita Solar PV Installed (Watts-DC/Person)			Potential Annual Growth Rate for Memphis (MW per Year)
	End of 2016	End of 2017	Delta	
	[1]	[2]	[3]	
Honolulu	495.2	606.4	111.2	72.5
Denver	66.4	120.3	53.9	35.2
Washington	37.5	69.4	31.9	20.8
San Antonio	79.5	107.9	28.4	18.5
San Jose	169.1	191.0	21.9	14.3

*Sources and Notes:*

[1], [2]: Environment America, “Shining Cities 2017” and “Shining Cities 2018”, Table: “Top 20 Solar Cities by Total Installed Solar PV Capacity”.

[3] = [2] – [1]

[4]: [3], multiplied by Memphis’ 2017 population (652,236), then converted to MW/year.

Memphis would need rapid solar buildout to achieve 350MW in time for 2024; the build-out rates implied by the Shining Cities reports are in DC terms, which need to be discounted by roughly 25% to be converted to AC terms, which is what gets delivered to the grid.<sup>17</sup> Accordingly, the average annual buildout rate would need to be somewhat higher, on a per-capita basis, than Honolulu experienced in 2017.<sup>18</sup> However, it is worth noting, as depicted in Figure 7, that nationwide solar development is projected to exceed that of 2017 in every year from 2019 to 2024, by as much as 50%, as PV installation costs drop and developers accelerate deployments before the scheduled declines in the level of the ITC. It is also worth noting that the Shining Cities reports capture only growth within the city limits, whereas MLGW would conceivably be able to develop solar installations throughout Shelby County. Furthermore, while the build-out rates are ambitious relative to other cities’ recent experiences, we are not aware of other cities having had specific medium-term targets that would induce them to build out solar capacity particularly rapidly.

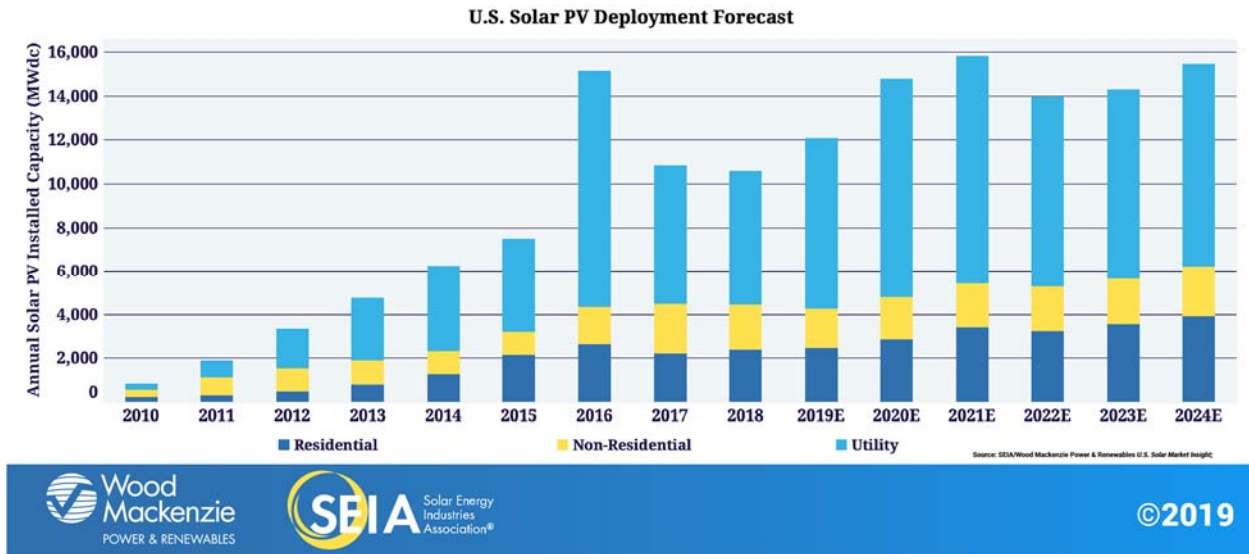
While more expensive than solar PV located outside of Memphis with more sunshine, local solar PV would also lead to some incremental economic activity that would offset at least some of the cost difference. For example, a previous Brattle Group study that analyzed the impact of First Solar’s Desert Sunlight Solar Farm and Gen-Tie Transmission Line in Riverside, California. The study found that the per MW of solar PV capacity the project was estimated to support about 3.5

<sup>17</sup> See, for example, Energy Information Administration, “Solar plants typically install more panel capacity relative to their inverter capacity,” March 18, 2018. Available at <https://www.eia.gov/todayinenergy/detail.php?id=35372>.

<sup>18</sup> If Memphis needs to add 70 MW AC of solar capacity per year, that is roughly 87.5 MW DC

full time equivalent jobs, \$414,727 in employee compensation and \$610,909 in total economic activity.<sup>19</sup>

**Figure 7: U.S. Solar PV Deployment Forecast (SEIA)**



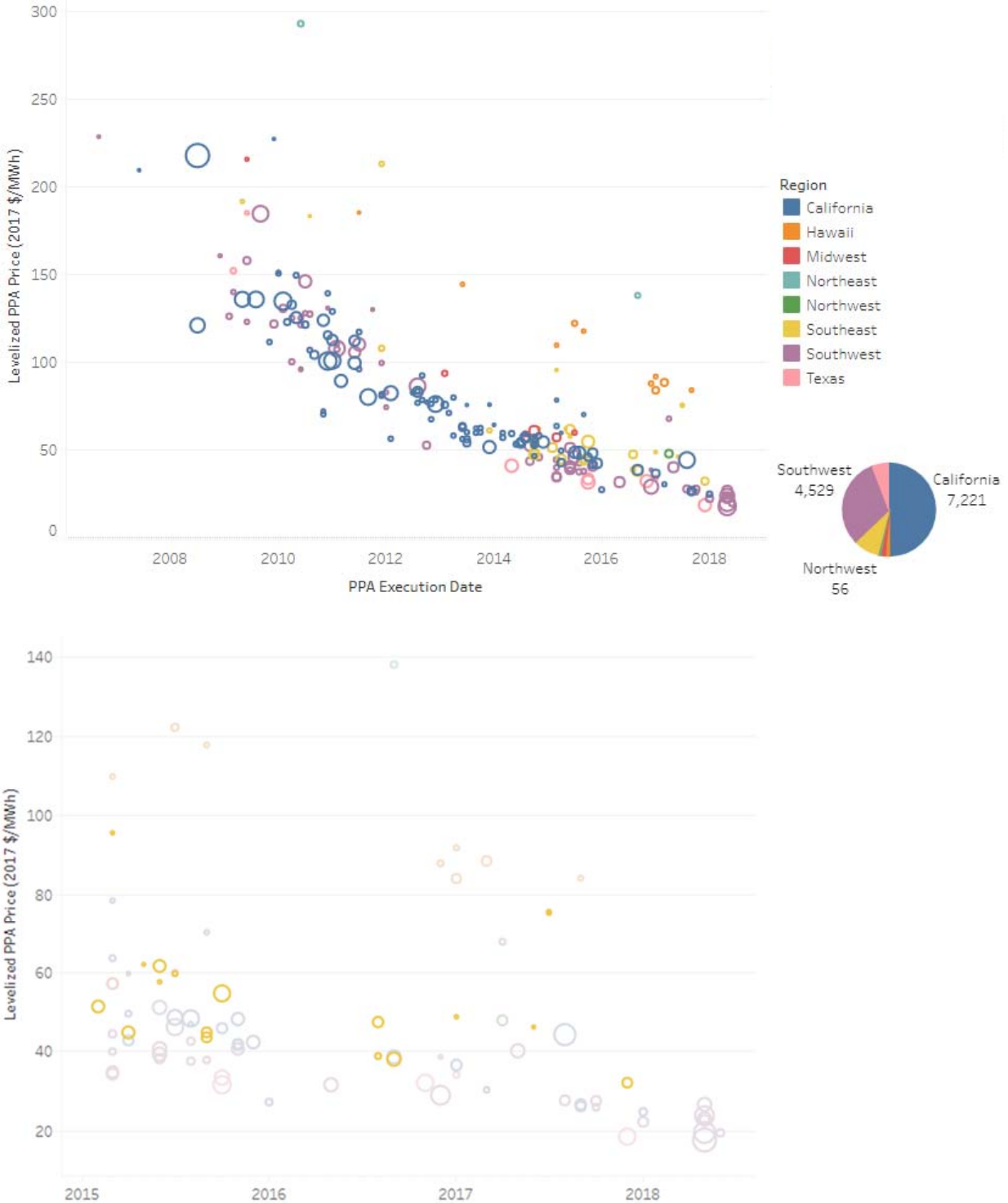
Source: Solar Energy Industries Association. <https://www.seia.org/solar-industry-research-data>

## 2. Benchmark against Other Sources

Data on historical PPAs for solar projects demonstrate that the cost estimates contained in the January 2019 Brattle report are reasonable. The top panel of Figure 8 illustrates the PPA prices of a wide variety of utility-scale solar projects since 2006, as compiled by LBNL. The second panel of Figure 8 focuses on PPA prices for projects developed in the southeastern United States between 2015 and 2018, indicating that PPA prices in the region are dropping much like those in the rest of the country, with recent projects as low as \$33/MW (3.3 cents per kWh).

<sup>19</sup> Mark Berkman, Michelle Tran and Wesley Ahlgren, Economic and Fiscal Impacts of the Desert Sunlight Solar Farm, The Brattle Group, 2011

**Figure 8: US Utility-Scale Solar PPA Prices, 2006-2018**



**Sources and Notes:**

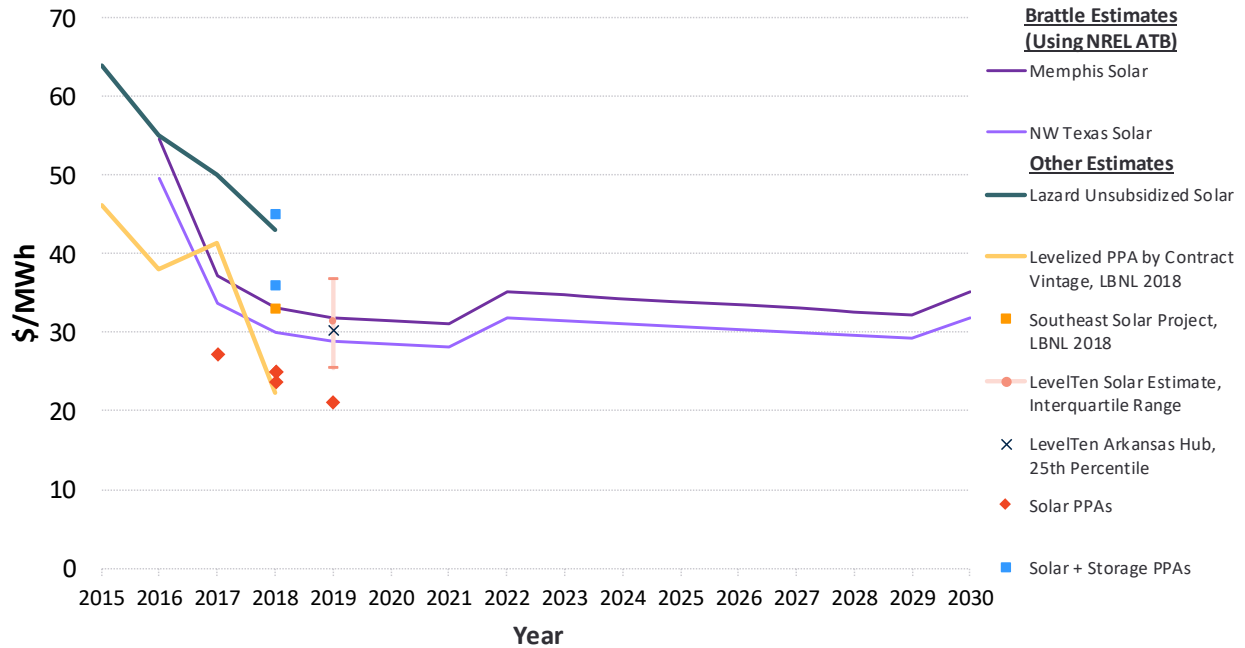
LNBL, <https://emp.lbl.gov/pv-ppa-prices>.

Size of circle reflects size of PV project.

Figure 9 compares Brattle’s cost estimates as presented in the January Report with data from the LBNL report and other third-party sources. Brattle’s estimates align with publically available

sources. PPA prices included in the figure are also listed in Table 4. As with wind resources, there is limited publically available data on PPA prices. In contrast to the wind projections discussed above, Brattle’s solar estimates do include the effects of the ITC, which will continue to impact prices over the next several years but will step down to 10% in 2022.

**Figure 9: Solar Costs Compared to Brattle Estimates**



**Sources and Notes:**

NREL ATB 2018; Lazard (<https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2018/>); Lawrence Berkeley National Laboratory Utility-Scale Solar 2018 (<https://emp.lbl.gov/utility-scale-solar/>); LevelTen Energy PPA Price Index, Q1 2019 (<https://leveltenenergy.com/blog/ppa-price-index/q1-2019/>).

Individual PPA points on the graph are shown at time of execution/announcement.

**Table 4: Recent US Solar PPAs**

Name	State	Type	Execution	Price
			Year	(\$/MWh)
Austin Energy	TX	Solar	2017	27.25
Central Arizona Project	AZ	Solar	2018	24.99
New Braunfels Utilities	TX	Solar	2018	25.00
NV Energy	NV	Solar	2018	23.76
Idaho Power	ID	Solar	2019	21.18
Tucson Electric Power	AZ	Solar + Storage	2017	45.00
Xcel Energy	CO	Solar + Storage	2018	36.00

*Sources and Notes:*

- Austin Energy: <https://www.greentechmedia.com/articles/read/amidst-201-trade-case-uncertainty-austin-energy-signs-historic-low-solar-pp#gs.h2re3r>
- Central Arizona Project: <https://www.greentechmedia.com/articles/read/arizona-water-provider-approves-lower-cost-solar-ppa-to-replace-coal#gs.elit26>
- New Braunfels Utilities: <https://www.greentechmedia.com/articles/read/utility-signs-new-low-solar-ppa-in-texas#gs.di8is5>
- NV Energy: <https://www.greentechmedia.com/articles/read/nevada-beat-arizona-record-low-solar-ppa-price#gs.elkla8>
- Idaho Power: <https://www.greentechmedia.com/articles/read/idaho-power-signs-super-low-solar-ppa-to-buoy-100-clean-energy-plans#gs.elpwum>

Several high-level findings are apparent from the data presented in this section:

- Texas and the western United States have seen solar PPA prices in the lower \$20s/MWh in recent years.
- Price for several recent solar PPAs in the Southeast have been below \$40/MWh, with prices as low as approximately \$33/MWh, according to LBNL.
- Recent prices for PPAs for solar plus storage have been as low as \$36/MWh.
- All of these projects benefit from a 30% investment tax credit (ITC), which will be phased down by 2022. But even without the ITC, current solar PV contract prices are below the current wholesale power rate paid by MLGW, even before accounting for expected further decreases in the cost of solar PV as described above and in the January report.

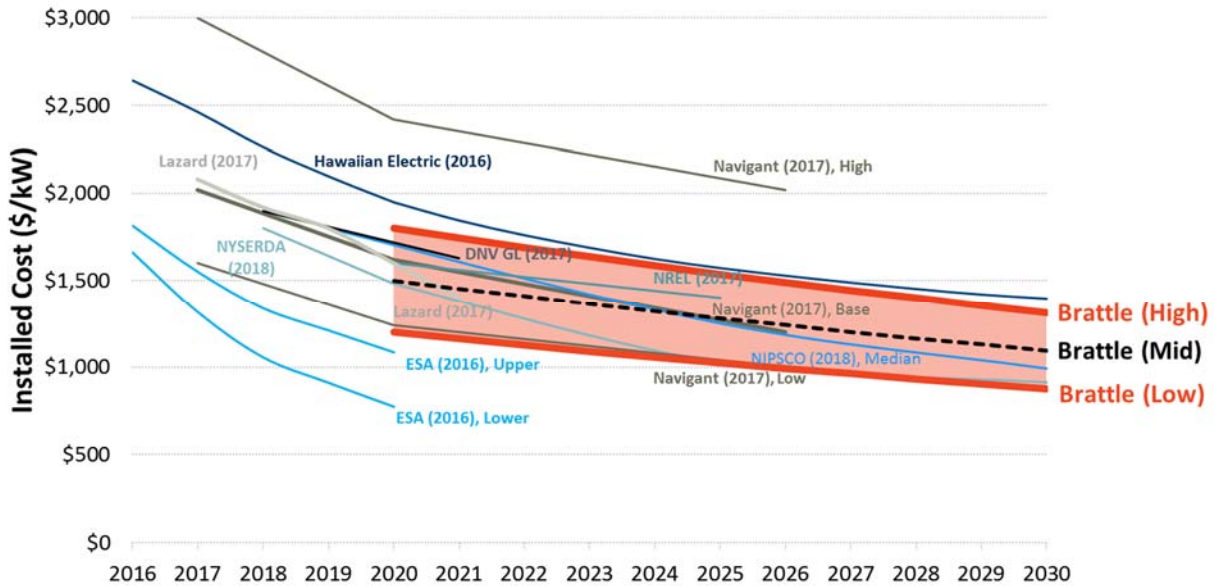
## C. Storage Cost Estimates

NREL ATB estimates for storage resources were not as developed as those for other resources.<sup>20</sup> Accordingly, the analysis for the January report relied on cost estimates from a range of publically

<sup>20</sup> For example, storage cost estimates are only provided for 5-year ranges as opposed to annually.

available sources, as first compiled for a previous Brattle study, shown in Figure 10 below.<sup>21</sup> The January 2019 report also maintained the previous Brattle assumption of a 15 year useful life for battery resources.<sup>22</sup> NREL ATB does provide fixed O&M estimates, which, due to the lack of other publically available data, the January report relied upon.

**Figure 10: Brattle Review of Installed Costs for Storage**



*Sources and Notes:*

The Brattle Group, [The Economic Potential for Energy Storage in Nevada](#)

Installed cost estimates for a 4-hour storage system. All values in nominal dollars. The Brattle (Mid) line is the average of the high and low estimates and was used in the report.

The chart above shows that energy storage costs have declined and will continue to do so over the next decade. Discussions with clients and other experts in the industry have led us to believe that our overnight costs estimates are conservative.

<sup>21</sup> Ryan Hledik, Judy Chang, Roger Lueken, Johannes Pfeifenberger, John Imon Pedtke, and Jeremy Vollen, “The Economic Potential for Energy Storage in Nevada,” The Brattle Group, pp. 23-25.

See <https://www.brattle.com/news-and-knowledge/publications/the-economic-potential-for-energy-storage-in-nevada>.

<sup>22</sup> *Ibid*, p. 23.

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