Levelized Cost of Solar Photovoltaics in North Carolina

NC SUSTAINABLE
ENERGY ASSOCIATION

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Mission:
Founded in 1978, the North Carolina Sustainable Energy Association is a 501(c)(3) non-profit membership organization of individuals, businesses, government and nonprofits working to ensure a sustainable future by promoting renewable energy and energy efficiency to the benefit of North Carolina through education, public policy, and economic development.

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EXECUTIVE SUMMARY

As of September 30, 2011, North Carolina ranked 8th in the U.S. for cumulative installed solar photovoltaic (PV) capacity.[1] As of October 31, 2011, there were 1,142 solar PV systems totaling over 128 megawatts of capacity registered with the North Carolina Utilities Commission to be installed in North Carolina from 2006 to 2011. These systems range in capacity from small residential systems to one of the largest solar projects on the East Coast, located in Davidson County.

Considering the robust growth of solar PV installations in North Carolina, the purpose of this report is to evaluate the cost of solar PV systems in relation to the retail price of electricity provided from electric utilities in North Carolina. In particular, the report considers when the declining cost of solar PV systems reaches grid parity or becomes equal to electricity prices in North Carolina. The report also considers the impact of PV system capacity and the presence or absence of federal and state tax credits on the cost of solar PV systems.

A key component of the research evaluated the levelized cost of energy (LCOE) of North Carolina solar PV systems. The LCOE of solar PV systems reflects the price at which energy must be sold to break even over the assumed economic life of the system. The LCOE equation takes into account system costs, as well as factors including financing, insurance, operations and maintenance, depreciation schedules and any applicable incentives. The analysis used the System Advisor Model (SAM) developed by the National Renewable Energy Laboratory[2] to calculate the LCOE under a series of ownership and systems capacity scenarios from 2006 to 2020. In addition, retail electricity prices were calculated for 2006 to 2020. Finally, the evaluation compared the LCOE of solar PV systems and the retail electricity prices in nine scenarios to identify if and when the declining LCOE of solar PV intersects with increasing retail electricity prices.

Key findings from this report include:

- For many electric utilities, solar PV systems greater than 10 kW with federal and state tax credits were at grid parity or cost competitive with commercial retail electricity prices in North Carolina in 2011.
- Solar PV systems greater than 500 kW with federal and state tax credits achieve grid parity or become cost competitive with commercial retail electricity prices for all North Carolina electric utilities in 2015.
- Solar PV systems greater than 10 kW through 500 kW with federal and state tax credits achieve grid parity or become cost competitive with commercial retail electricity prices for all North Carolina electric utilities in 2018.
- Solar PV systems 10 kW or less taking federal and state tax credits achieve grid parity or become cost competitive with residential retail electricity prices for the majority of North Carolina electric utilities in 2020.
- For many electric utilities, solar PV without federal and state tax credits will be at grid parity or cost competitive with retail electricity prices in North Carolina in 2020.

[1] Solar Energy Industries Association and GTM Research. (2011). *U.S. Solar Market Insight Report, Q3 2011, Full Report.*
[2] Available at https://sam.nrel.gov.

ADOPTION OF SOLAR PHOTOVOLTAIC SYSTEMS IN NORTH CAROLINA

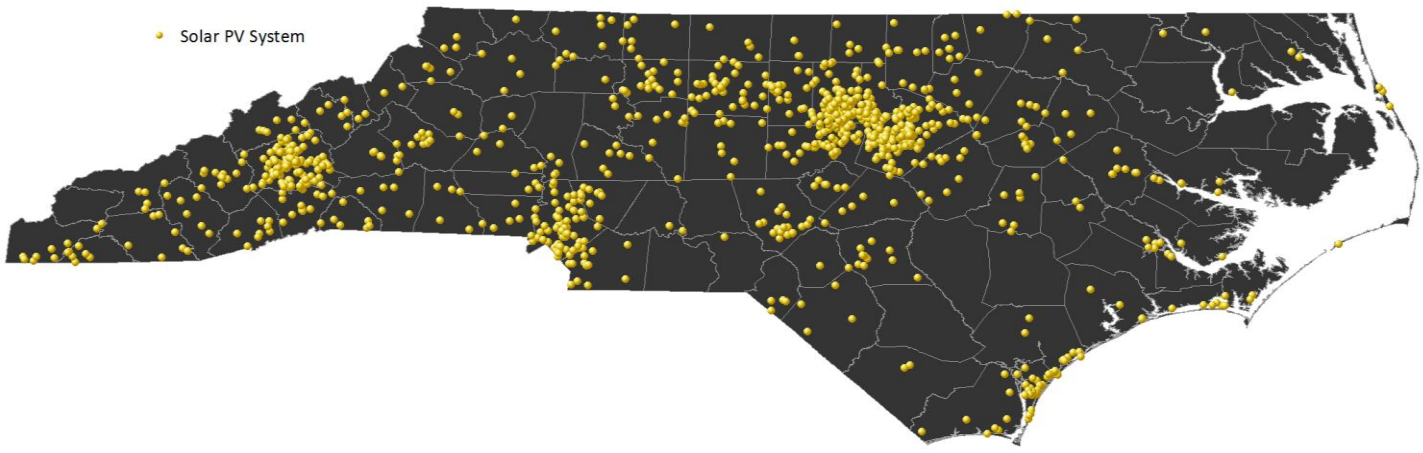
As of September 30, 2011, North Carolina ranked 8th in the U.S. for cumulative installed solar photovoltaic (PV) capacity.[3] As of October 31, 2011, there were 1,142 solar PV systems totaling over 128 megawatts (MW) of capacity registered with the North Carolina Utilities Commission (NCUC) to be installed in North Carolina from 2006 to 2011 (see Table 1 and Figure 1).[4] These systems range in capacity from small residential systems to one of the largest solar projects on the East Coast located in Davidson County.

Table 1. ***Megawatts (MW) of Registered Solar PV Capacity in North Carolina Expected Online from 2006-2011.***

Expected Year Online	Capacity MW DC[(a)]	Number of Systems	Solar PV System Capacity		
			10 kW or Less	Greater than 10 kW through 500 kW	Greater than 500 kW
2006	0.26	24	22	2	0
2007	0.32	54	50	4	0
2008	5.49	116	105	7	4
2009	25.88	199	167	24	8
2010	28.43	352	283	57	12
2011[(b)]	67.94	397	300	70	27
TOTAL	**128.32**	**1,142**	**927**	**164**	**51**

Notes: (a) Solar PV systems produce electricity in direct current (DC), which is converted by inverters to alternating current (AC), the typical current used throughout the U.S. electric grid. As a result, it is normal industry practice to report solar PV capacity in DC units. For the purpose of this report, 15.5 MW of reported AC capacity in 2010 and 18.4 MW of reported AC capacity in 2011were converted to the equivalent DC capacity.
(b) 2011 data is for NCUC filings through October 31, 2011.
Sources: NC Sustainable Energy Association, NC Utilities Commission.

Figure 1. ***Geographic Distribution of Solar PV Capacity in North Carolina Online from 2006-2011.***



Note: Data is through October 31, 2011. Sources: NC Sustainable Energy Association, NC Utilities Commission.

[3] Solar Energy Industries Association and GTM Research. (2011). *U.S. Solar Market Insight Report, Q3 2011, Full Report..*
[4] Data is collected from Small Power Producer and Electric dockets filed at the NCUC. Not included in this report are registered solar PV systems with installation dates prior to 2006, with installation dates in 2012, or systems registered outside of North Carolina.

Primary drivers influencing the growth of solar PV installations include a steep decline in the installed cost of systems and North Carolina's policy environment. Declining PV module costs and growing expertise within the industry are driving down costs for solar PV in U.S. and North Carolina markets. The national trend for the cost of solar PV modules declined 37% from 2008 to 2010. Meanwhile, non-module costs decreased 18% from 2009 to 2010.[5] These national trends are evident in the North Carolina market as the installed cost per Watt (W) of solar PV in North Carolina decreased 36% from $8.50/W in 2006 to $5.44/W in 2011.[6] A host of factors are driving the decline in cost, including improvements to existing technologies, cost-cutting measures in the supply chain, economies of scale in production and procurement and the professional expertise to streamline permitting, installation and other associated project elements that organically develop in any industry as it matures.

In addition to market dynamics, North Carolina has enacted several policies that facilitate the adoption of solar energy. A major driver is the North Carolina Renewable Energy and Energy Efficiency Portfolio Standard (REPS).[7] Adopted in 2007, this state policy requires North Carolina's investor-owned utilities to generate at least 12.5% of their annual retail electric sales from a combination of renewable energy and energy efficiency resources by 2021, including at least 0.2% of retail electric sales from solar energy. Cooperative and municipal electric utilities must meet a 10% requirement by 2018, including at least 0.2% of retail sales from solar energy. The growth of solar PV in North Carolina has also been fostered by the existence of NC GreenPower, an independent nonprofit that supports small renewable energy systems by collecting voluntary contributions from electric customers in North Carolina.

Compliance with the North Carolina REPS and management of NC GreenPower are both dependent on renewable energy certificates (RECs). A single REC is created through electric generation from solar PV systems and other qualifying renewable energy technologies. A single REC is equal to 1 megawatt-hour of solar electricity and represents the fact that the electricity was generated from a renewable resource. RECs are tradable commodities that can be sold to electric utilities for compliance with the North Carolina REPS or to NC GreenPower to retire as part of the voluntary renewable energy program. A single REC can be used for either of the North Carolina REPS or NC Green Power program – not both.

Additional North Carolina policy drivers include a 35% state investment tax credit through 2015[8] and a property tax exemption of 80% for commercial and 100% for residential PV systems.[9] Solar PV installations in North Carolina also benefit from federal energy policies, particularly a 30% federal investment tax credit. Commercial projects are also eligible for accelerated depreciation through the Modified Accelerated Cost Recovery System. See the *Database of State Incentives for Renewables and Efficiency* for greater detail on these and other related policies and incentives.[10]

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[5] Barbose, Galen et al. (2011, September). *Tracking the sun IV: An Historical Summary of the Installed Cost of Photovoltaics in the United States from 1998 to 2010*. Lawrence Berkeley National Laboratory Environmental Energy Technologies Division. Available at http://eetd.lbl.gov/ea/ems/reports/lbnl-5047e.pdf [November 19, 2011].

[6] The average cost per Watt for solar PV is derived from 1,037 Small Power Producer (SP) Dockets filed at the NCUC.

[7] North Carolina General Statute § 62-133.8. Renewable Energy and Energy Efficiency Portfolio Standard (REPS).

[8] North Carolina General Statute § 105-129.16A. Credit for investing in renewable energy property.

[9] North Carolina General Statute § 105-274. Property Subject to Taxation. Additional detail from the North Carolina Department of Revenue can be found at http://www.dornc.com/taxes/property/memos/solar_energy.pdf [December 2, 2011].

[10] Available at http://www.dsireusa.org.

SUMMARY OF METHODOLOGY

Considering the robust growth of solar PV installations in North Carolina, the purpose of this report is to evaluate the cost of solar PV systems in relation to the retail electricity price charged by electric utilities in North Carolina. In particular, the report evaluates when the declining cost of solar PV systems will reach "grid parity" – the point at which the amortized cost of a solar PV system becomes equal to retail electricity prices in North Carolina. The report also evaluates the impact of PV system capacity and the presence or absence of federal and state tax credits on the cost of solar PV systems. This analysis was conducted in three phases as outlined below.

It is important to note that the numbers presented in this report are projections based on historical trends in North Carolina. As with any projection, there is a degree of uncertainty within the modeled parameters that increases the further they are modeled into the future. This report is intended to be useful to evaluate the near-term trends for solar PV system grid parity with electric retail prices; however, changes in parameters can significantly alter the results of this analysis.

(1) Calculating the Levelized Cost of Energy (LCOE) of Solar PV Systems

This research estimated and evaluated the levelized cost of energy (LCOE) of solar PV systems. The LCOE of solar PV systems reflects the price at which energy must be sold to break even over the assumed economic life of the system.[11] Stated another way, it is the cost incurred to install and maintain an energy-producing system divided by the energy the system will produce over its lifetime of operation:

$$LCOE = \frac{Lifetime\ Cost}{Lifetime\ Energy\ Production}$$

This equation yields a net present value in the familiar cents per kilowatt-hour (kWh) of electricity generated. This is an assessment of the economic lifetime energy cost and energy production and can be applied to essentially any energy technology. It is frequently used to evaluate a technology or energy system against electricity purchased from the grid.[12] The LCOE equation takes into account system costs, as well as factors including financing, insurance, operations and maintenance (O&M), depreciation and any applicable incentives. Installed costs are a primary driver for solar PV systems as they lack fuel costs and require minimal O&M.

Historical installed costs were derived from 1,037 PV systems registered with the NCUC that contain cost data and evaluated in three categories based on system capacity (see Table 2). Systems were categorized and analyzed by their expected installation date, not the registration date with the NCUC. Significant outliers were removed before data analysis. Within each category of system capacity, the mean installed cost was calculated for 2006 to 2011, where data was available. Projected costs for solar PV systems for 2012 through 2020 were modeled from historical data, bounded by an assumption that the installed cost of solar PV systems do not drop below $1 per Watt.

[11] Darling, Seth et al. (2011, February). "Assumptions and the levelized cost of energy for photovoltaics." *Energy & Environmental Science*, Volume 4, Issue 9, pages 3133-3139.

[12] Branker, Kadra et al. (2011, December). "A review of solar photovoltaic levelized cost of electricity." *Renewable and Sustainable Energy Reviews*, Volume 15, Issue 9, Pages 4470-4482.

Table 2. ***Registered Solar PV Systems in North Carolina Reporting Cost and Installation from 2006-2011.***

Solar PV Systems by Capacity	2006	2007	2008	2009	2010	2011
10 kW or Less	22	49	98	165	270	282
Greater than 10 kW through 500 kW	2	4	7	20	37	57
Greater than 500 kW	0	0	0	0	7	17
TOTAL	**24**	**53**	**105**	**185**	**314**	**356**

Note: Data is through October 31, 2011. Sources: NC Sustainable Energy Association, NC Utilities Commission.

Once installed figures were calculated, the analysis used the System Advisor Model (SAM) developed by the National Renewable Energy Laboratory[13] to calculate the LCOE of a solar PV system installed in Raleigh, North Carolina each year from 2006 to 2020, where data was available. Systems that were 10 kW or less in capacity were assumed to be residential installations with residential ownership for tax purposes. The two larger system categories were assumed to be commercial installations with commercial ownership for tax purposes. In addition, a key variable considered within each capacity category was the presence or absence of the 30% federal tax credit and 35% state tax credit. While the federal and state tax credits are set to expire at the end of 2016 and 2015 respectively, this analysis assumes their existence through 2020. The final outcome was six LCOE trend lines for solar PV systems in North Carolina (see Table 3). A full set of assumptions used within the LCOE modeling can be found in Appendix A.

Table 3. ***LCOE Trend Lines Modeled for Solar PV Systems in North Carolina.***

System Capacity	System Ownership	Tax Credits	Timeframe
10 kW or Less	Residential	With Tax Credits	2006 to 2020
10 kW or Less	Residential	Without Tax Credits	2006 to 2020
Greater than 10 kW through 500 kW	Commercial	With Tax Credits	2006 to 2020
Greater than 10 kW through 500 kW	Commercial	Without Tax Credits	2006 to 2020
Greater than 500 kW	Commercial	With Tax Credits	2010 to 2020
Greater than 500 kW	Commercial	Without Tax Credits	2010 to 2020

(2) Calculating Retail Electricity Prices for Residential and Commercial Customers

Historical electricity prices were derived from data collected from the Energy Information Administration. Historical retail electricity prices for 2001 through 2010 were categorized by (1) residential or customer class and (2) type of electric utility (cooperative, investor-owned, or municipal utility). This report considered electricity prices for 31 cooperative, 71 municipal and 3 investor-owned electric utilities. Electricity prices were modeled for 2011 to 2020 using historical data for each electric utility. The highest retail price, median retail price, and lowest retail price for cooperative and municipal utilities were used to generate an electricity price band for residential and commercial customers for each of these utility types. It should be noted that this analysis examines retail electricity prices and not retail electricity rates, because the available data does not compile the variety of rates offered to residential and commercial electric customers. In addition, the number of utility customers used in this report reflects figures from

[13] Available at https://sam.nrel.gov.

2010. These figures remain constant in the analysis and are not projected for future years. Additional details concerning electricity price calculations can be found in Appendix A.

(3) Evaluating Grid Parity - Comparing LCOE of Solar PV Systems and Retail Electricity Prices

The final stage of analysis was generating nine scenarios that compare the LCOE of solar PV systems and the retail electricity prices of various electric utilities (see Table 4). The final stage was designed to identify if and when the declining LCOE of solar PV intersects with the increasing retail electricity prices. The term frequently used to describe this intersection is "grid parity".

This analysis evaluates the LCOE of solar PV systems reaching grid parity with retail electricity prices in two ways. First, the analysis calculates the percentage of utilities where solar PV systems meet grid parity with retail electricity prices. Second, the analysis calculates the number of residential or commercial electric customers served by a utility where solar PV systems meet grid parity with retail electricity prices. The percent of utilities and number of customers calculated for each year are considered within each of the nine evaluated scenarios.

Table 4. ***Nine Grid Parity Scenarios Evaluated within Report.***

	Solar PV System Capacity	Retail Electricity Price	System Ownership	Electric Utility	Variables
Scenario 1	10 kW or less	Residential	Residential	Cooperatives	Federal & State Tax Credits
Scenario 2	10 kW or less	Residential	Residential	Municipals	Federal & State Tax Credits
Scenario 3	10 kW or less	Residential	Residential	Investor-Owned	Federal & State Tax Credits
Scenario 4	Greater than 10 kW through 500 kW	Commercial	Commercial	Cooperatives	Federal & State Tax Credits
Scenario 5	Greater than 10 kW through 500 kW	Commercial	Commercial	Municipals	Federal & State Tax Credits
Scenario 6	Greater than 10 kW through 500 kW	Commercial	Commercial	Investor-Owned	Federal & State Tax Credits
Scenario 7	Greater than 500 kW	Commercial	Commercial	Cooperatives	Federal & State Tax Credits
Scenario 8	Greater than 500 kW	Commercial	Commercial	Municipals	Federal & State Tax Credits
Scenario 9	Greater than 500 kW	Commercial	Commercial	Investor-Owned	Federal & State Tax Credits

RESULTS OF ANALYSIS

Levelized Cost of Energy (LCOE) of Solar PV Systems

The installed cost of solar PV systems, is the largest component of the LCOE, and has declined steadily in North Carolina (see Table 5). For solar PV systems 10 kW or less, average costs have declined 24% - from $9.00/W in 2006 to $6.84/W in 2011. The installed cost of solar PV systems greater than 10 kW through 500 kW has declined 33% from $8.00 in 2006 to $5.33 in 2011. The historical cost declines are comparable to declines in the installed cost of solar PV found throughout the United States.

The installed cost of solar PV systems in North Carolina is estimated to continue to decline in the future. In 2020, the installed cost of solar PV systems less than 10 kW are expected to be $3.84/W while solar PV systems greater than 500 kW are expected to be $1.90/W. Similar to historical data, the projected installed cost figures are comparable to a sampling of projections from respected national and international energy sources.

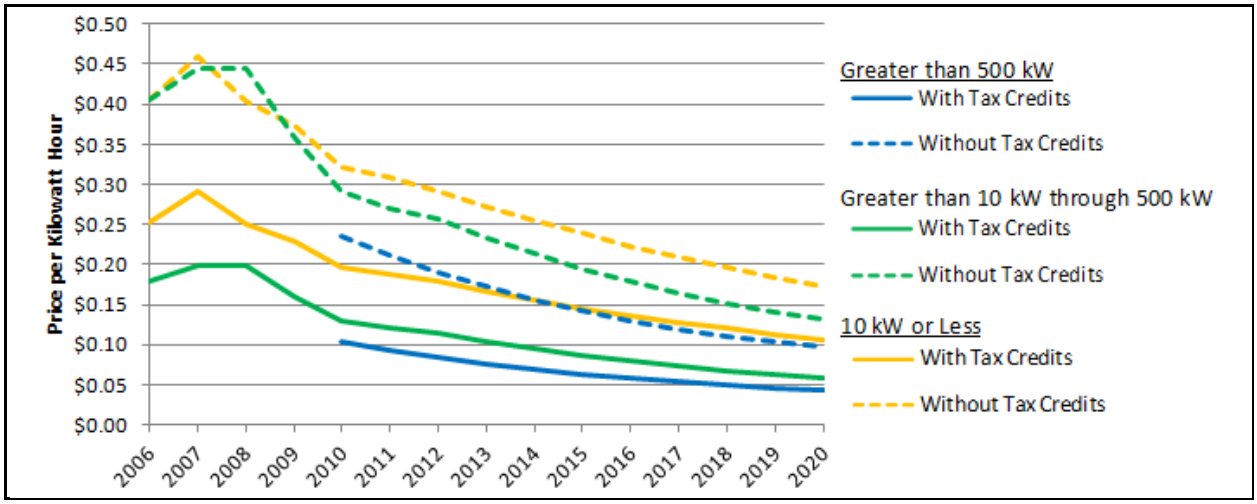
Table 5. ***Historical and Projected Installed Cost of Solar PV Systems in North Carolina.***

		10 kW or Less	Greater than 10 kW through 500 kW	Greater than 500 kW	Comparison with Select Data
Historical $/W	2006	$9.00	$8.00	-	$7.90[(a)]
	2007	$10.15	$8.77	-	$7.90[(a)]
	2008	$8.91	$8.77	-	$7.60[(a)]
	2009	$8.27	$7.05	-	$7.50[(a)]
	2010	$7.11	$5.75	$4.63	$6.20[(a)]
	2011	$6.84	$5.33	$4.16	-
Projected $/W	2012	$6.47	$5.05	$3.75	-
	2013	$6.04	$4.60	$3.39	-
	2014	$5.65	$4.20	$3.08	-
	2015	$5.28	$3.84	$2.80	$2.30 - $2.70[(b)]
	2016	$4.94	$3.53	$2.57	$2.20[(c)]
	2017	$4.63	$3.24	$2.36	$1.00[(c)]
	2018	$4.35	$2.99	$2.19	-
	2019	$4.08	$2.77	$2.03	-
	2020	$3.84	$2.58	$1.90	$1.45[(d)] - $2.70[(e)]

Notes: (a) Barbose et al, 2011; (b) US Department of Energy's Solar America Initiative, range is for "residential" and "commercial" solar respectively; (c) US Department of Energy's SunShot Initiative; (d) Bloomberg New Energy Finance; (e) International Energy Association's Photovoltaic Roadmap
Sources: NC Utilities Commission, NC Sustainable Energy Association

The installed cost figures were used to model six LCOE trend lines for solar PV systems in North Carolina. Reflecting the downward trend in the installed cost of solar PV systems, the LCOE trend lines decline steadily throughout the study period (see Figure 2). The presence of federal and state tax credits has a significant impact in lowering the LCOE of solar PV systems within the three capacity categories evaluated.

Figure 2. ***LCOE Trend Lines of Solar PV in North Carolina from 2006-2020.***



Note: Systems of 10 kW or less are assumed to have residential ownership for tax purposes.
Sources: National Renewable Energy Laboratory, NC Sustainable Energy Association, NC Utilities Commission.

Retail Electricity Prices for Residential and Commercial Customers

Projected electricity prices increased at an average annual change ranging from 0.1% to 3.5% for residential electricity prices and 0.5% to 3.5% or commercial electricity prices (see Table 6).

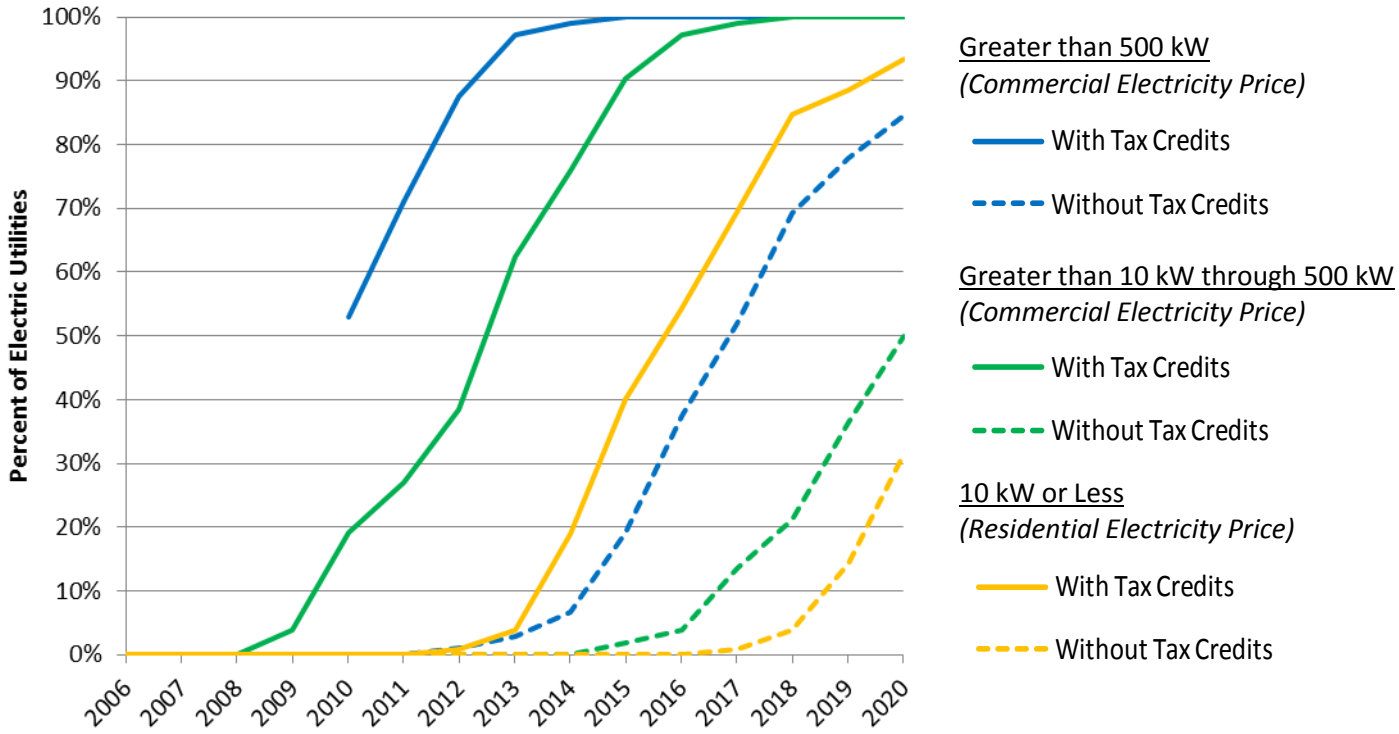
Table 6. ***Projected Average Annual Change in Residential and Commercial Electricity Prices 2010-2020.***

Electric Utility	Average Annual Change in Residential Electricity Prices 2010 - 2020			Average Annual Change in Commercial Electricity Prices 2010 - 2020		
	High Price	Median Price	Low Price	High Price	Median Price	Low Price
Cooperative	3.4%	2.9%	3.5%	3.5%	2.5%	2.9%
Municipal	2.6%	2.5%	0.1%	2.6%	1.9%	0.5%
Duke Energy	1.3%			1.4%		
Progress Energy	2.4%			2.4%		
Dominion North Carolina	1.3%			1.7%		

Grid Parity - Comparing LCOE of Solar PV Systems and Retail Electricity Prices

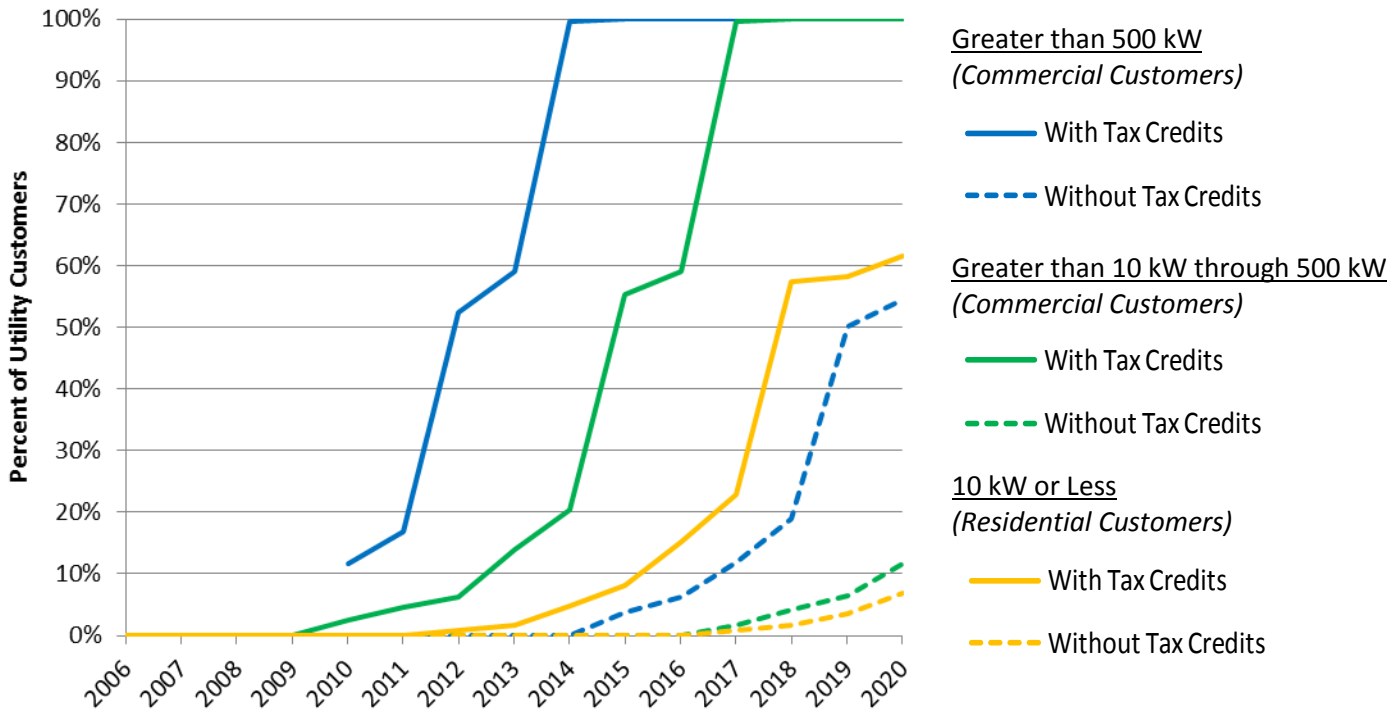
Comparing the LCOE of solar PV systems and retail electricity prices in North Carolinas show a growing number of electric utilities and electric customers experiencing grid parity (see Figures 3 and 4). This trend is primarily driven by declining LCOE of solar PV systems. A contributing, but secondary factor, is the increasing price of retail electricity. These dynamics can be examined more fully in Appendix C.

Figure 3. ***Percentage of Electric Utilities at Grid Parity with LCOE of Solar PV Systems from 2006-2020.***



Note: Systems of 10 kW or less are assumed to have residential ownership for tax purposes.
Sources: National Renewable Energy Laboratory, NC Sustainable Energy Association, NC Utilities Commission.

Figure 4. ***Percentage of Electric Customers at Grid Parity with LCOE of Solar PV Systems from 2006-2020.***



Note: Systems of 10 kW or less are assumed to have residential ownership for tax purposes.
Sources: National Renewable Energy Laboratory, NC Sustainable Energy Association, NC Utilities Commission.

CONCLUSIONS

For many electric utilities, solar PV systems greater than 10 kW with federal and state tax credits were at grid parity or cost competitive with commercial retail electricity prices in North Carolina in 2011.

The LCOE of solar PV systems greater than 500 kW taking federal and state tax credits was $0.09/kWh in 2011. This figure was at or below the retail commercial electricity prices for 74 of the 104 electric utilities, or 71% of utilities in North Carolina. These cooperative and municipal electric utilities at grid parity serve over 107,000 commercial customers in North Carolina. However, grid parity was not present with commercial electricity prices provided by investor-owned utilities, which serve 71% of the commercial customers in North Carolina.

The LCOE of solar PV for systems greater than 10 kW through 500 kW was also found to be at grid parity in certain instances. The LCOE of these systems with federal and state tax credits was $0.12/kWh in 2011, which was at or below the retail commercial electricity prices for 28 of the 104 electric utilities, or 27% of the electric utilities in North Carolina. These cooperative and municipal electric utilities serve over 28,000 commercial customers in North Carolina.

Several scenarios produced results where the LCOE of solar PV system was not at grid parity with electricity prices in North Carolina in 2011. The removal of federal and state tax credits from the commercial solar PV systems noted above resulted in installations that were not at grid parity with any commercial electricity prices in North Carolina. Further, solar PV systems 10 kW or less taking federal and state tax credits demonstrated a significantly higher LCOE of $0.19/kWh in 2011. This higher LCOE figure reflects economies of scale achieved in larger installations and tax depreciation benefits from commercial ownership. As a result, solar PV systems 10 kW or less were not at grid parity with residential electricity prices for any electric utility in North Carolina in 2011.

Solar PV systems greater than 500 kW with federal and state tax credits achieve grid parity or become cost competitive with commercial retail electricity prices for all North Carolina electric utilities in 2015.

The LCOE of solar PV systems greater than 500 kW with federal and state tax credits is $0.06/kWh in 2015. This LCOE figure is at or below the projected retail commercial electricity price for all 104 electric utilities in North Carolina. Solar PV achieves full grid parity with retail commercial electricity prices within all cooperative utilities in 2012, all investor-owned utilities in 2014, and all municipal utilities in 2015.

In the absence of the federal and state tax credit in 2015, the LCOE of solar PV systems greater than 500 kW increases to $0.14/kWh. The result is an LCOE figure at or below the projected retail commercial electricity price for only 20 electric utilities in North Carolina in 2015.

Solar PV systems greater than 10 kW through 500 kW with federal and state tax credits achieve grid parity or become cost competitive with commercial retail electricity prices for all North Carolina electric utilities in 2018.

The LCOE of solar PV systems greater than 10 kW through 500 kW with federal and state tax credits is $0.07/kWh in 2018. This LCOE figure is at or below the projected retail commercial electricity price for all 104 electric

utilities in North Carolina. Solar PV achieves full grid parity with retail commercial electricity prices within all cooperative utilities in 2015, all investor-owned utilities in 2017, and all municipal utilities in 2018.

In the absence of the federal and state tax credit in 2018, the LCOE of solar PV systems greater than 10 kW through 500 kW climbs to $0.15/kWh. The result is an LCOE figure at or below the projected retail commercial electricity price for 22 electric utilities in North Carolina in 2018.

Solar PV systems 10 kW or less taking federal and state tax credits achieve grid parity or become cost competitive with residential retail electricity prices for the majority of North Carolina electric utilities in 2020.

The LCOE of solar PV systems 10 kW or less with federal and state tax credits is $0.11/kWh in 2020. This LCOE figure is at or below the projected retail residential electricity price for 97 of 105 electric utilities,[14] or 92% of the electric utilities in North Carolina. Solar PV achieves grid parity with retail residential electricity prices within all cooperative utilities in 2018, and the majority of investor-owned and municipal utilities in 2020. These electric utilities at grid parity serve nearly 2.5 million residential customers, or 62% of residential customers in North Carolina. Solar PV does not achieve grid parity with residential electricity prices offered by Duke Energy, which serves 1.1 million residential customers in North Carolina.

In the absence of the federal and state tax credit, the LCOE of solar PV systems increases to $0.17/kWh in 2020. The result is an LCOE figure at or below the projected retail residential electricity price for 33 electric utilities in North Carolina in 2015. The number of residential customers served by electric utilities at grid parity drops dramatically to 96,000 customers.

For many electric utilities, solar PV without federal and state tax credits will be at grid parity or cost competitive with retail electricity prices in North Carolina in 2020.

In 2020, the LCOE of solar PV systems greater than 500 kW without federal and state tax credits is $0.10/kWh. These systems will be at grid parity with commercial electricity prices for 88 electric utilities in North Carolina, including all cooperative utilities and the majority of municipal and investor-owned utilities. These electric utilities currently serve 350,000 commercial customers, or 54% of all commercial customers in North Carolina.

The LCOE of solar PV systems greater than 10 kW through 500 kW without federal and state tax credits is $0.13/kWh in 2020. These systems will be at grid parity with commercial electricity prices for 52 cooperative and municipal electric utilities in North Carolina. These electric utilities serve over 75,000 commercial customers today. These systems will not be at grid parity with commercial electricity prices of investor-owned utilities.

Finally, the LCOE of solar PV systems 10 kW or less without federal and state tax credits is $0.17/kWh in 2020. These systems will be at grid parity with residential electricity prices for 33 cooperative and municipal electric utilities in North Carolina. As noted earlier, these electric utilities serve 96,000 residential customers.

[14] There is one electric utility that serves just residential customers.

APPENDIX A: DETAILED METHODOLOGY & ASSUMPTIONS

A summary of the methodology employed in this research can be found in the body of this report. Additional technical detail and assumptions for the LCOE of solar PV systems are provided in this appendix.

Calculating the Levelized Cost of Energy (LCOE) of Solar PV Systems

Modeling the historical and future installed cost of solar PV systems involved multiple steps. Within each year of historical data collected from the NCUC, the mean installation cost of solar PV was calculated for each system capacity category considered within this report. Raw data was used for any year within a capacity category with 10 or fewer systems. Outliers were removed within other years by excluding any installations that were greater or less than one standard deviation of the mean within the respective year and capacity category. This resulted in the removal of 115 systems 10 kW or less; 15 systems greater than 10 kW through 500 kW; and six systems 500 kW or greater. From this adjusted data, an exponential regression was calculated for each solar PV system capacity category for 2006 through 2011, were data was available. This exponential regression, which was restricted to approaching a minimum installed cost of $1 per Watt, was used to project installed cost for 2012 through 2020.[15] The minimum cost of $1 per Watt was established from a literature review to reflect anticipated future solar PV installation costs. Effectively, even a "free" solar PV system requires installation labor, which establishes a hard lower bound on installed costs.

When calculating the LCOE of solar PV systems, the system costs filed with the NCUC were assumed to include sales tax and operation and maintenance costs as these services are typically included in contract prices. Within SAM, the analysis was conducted with the PVWatts System Model. For the two larger system capacity classifications, it was assumed the project was financed through a power purchase agreement (PPA). In addition, the LCOE of solar PV was made more conservative by incorporating an additional 2% return to the developer profits captured in installed cost figures.

Raleigh was chosen for the system location because it provided the median estimated annual energy output of the six North Carolina cities available within SAM. Choosing alternate North Carolina locations were found to have minimal impact on annual generation. Compared to a solar PV system in Raleigh, a system installed in Cape Hatteras would produce 0.8% more electricity in the first year of generation while a system in Asheville would produce 1.5% less electricity in the first year of generation. Additional assumptions employed in the SAM program are provided in Table 7. In addition, the key assumptions and LCOE for solar PV systems greater than 500 kW in capacity are compared to nationally recognized LCOE studies in Table 8.

Calculating Retail Electricity Prices for Residential and Commercial Customers

Data for each electric utility was obtained for each North Carolina electric utility from the Energy Information Administration from Form 861 for all years from 2001 to 2010. This data set contains information on electric utility revenue, electricity sales and customers served across multiple customer classes. For 2001 through 2010, the historical retail electricity price for residential and commercial customer classes for each electric utility was calculated by dividing

[15] Modeling methodology adapted from: Peterson, John. (2004). *Technical Mathematics, 3rd Edition.* Delmar Learning. *Pg. 539-540.*

total revenue by the amount of electricity sold.[16] From these figures, a linear regression was modeled for residential and commercial customer classes for each utility. The resulting equations were used to project residential and commercial retail electric prices forward for each utility for 2011 through 2020.

In certain instances, historical data was highly variable and linear regressions did not produce a meaningful trend line. For these cases – which account for fewer than 5% of the modeled figures – an average annual price increase of 1.66% was employed. This figure was derived from the Energy Information Administration's Annual Energy Outlook 2011 Report. For cooperative and municipal electric utilities, the results were used to generate yearly retail electricity price bands consisting of the highest retail electricity price, the median retail electricity price, and the minimum retail electricity price for residential and commercial customers within each year of projections.

[16] This same method was used in National Renewable Energy Laboratory's "Break-even cost for residential photovoltaics in the United States: key drivers and sensibilities" report by Denholm, Margolis, Ong and Roberts (12/2009).

Table 7. ***Key Data Inputs for the System Advisor Model LCOE Calculation.***

SAM Fields	10 kW or less	Greater than 10 kW through 500 kW	Greater than 500 kW
SAM Financing Option	Residential	Commercial PPA	Commercial PPA
Federal Taxes Marginal Income Tax Rate	28%	34%	34%
Federal Taxes Investment Tax Credit	30%	30%	30%
North Carolina Taxes Marginal Income Tax Rate	7%	6.9%	6.9%
North Carolina Taxes Tax Credit[(a)]	*25.2% (max = $10,500)*	*23.1% (max = $2.5 million)*	*23.1% (max = $2.5 million)*
Property Tax County & City Tax Rate	0.9075%	0.9075%	0.9075%
Property Tax Assessed Percent	0%	20%	20%
Depreciation	No Depreciation	5-year modified accelerated cost recovery system	5-year modified accelerated cost recovery system
Loan	7.75% for 10 years for 50% of the total cost	6% interest for 10 years for 50% of the total cost	6% interest for 10 years for 50% of the total cost
Tilt of System	36 degree tilt (fixed system)	36 degree tilt (fixed system)	36 degree tilt (fixed system)
Azimuth	180 Degrees	180 Degrees	180 Degrees
Derate Factor	84% DC to AC	84% DC to AC	84% DC to AC
System Degradation Rate	0.5% per year	0.5% per year	0.5% per year
Economic Life of System	20 years	20 years	20 years
Geographic Location	Raleigh, North Carolina	Raleigh, North Carolina	Raleigh, North Carolina
Real or Nominal Dollars	Nominal	Nominal	Nominal

Note: (a) North Carolina has a 35% state tax credit for investments in renewable energy technologies. The figures entered into the SAM model are adjusted downward to reflect the effective tax credit after accounting for interactions between federal and state taxes. However, the figure and results do not correct for the time value of money as the North Carolina tax credit is received over multiple years.

Table 8. ***Comparison of LCOE Research Assumptions.***

LCOE Variable	North Carolina Sustainable Energy Association	Electric Power Research Institute[17]	Lazard[18]
System Capacity	Greater than 500 kW	10 MW	10 MW
Installed Cost	$4.16 - $6.84/Watt in 2011	$3.70 - $5.00/Watt in 2015	$2.50 - $4.50/Watt in 2011
Fixed Operations and Maintenance	Included in installed cost	$50 - $65 kW/year	$15 - $25 kW/year
Capacity Factor	16%	15 - 28%	20 - 27%
Economic Life of System	20 years	20 years	20 years
Tax Credits	30% Federal Tax Credit & 35% State Tax Credit	No incentives	30% Federal Tax Credit
Federal Depreciation	Yes	Yes	Yes
Federal Marginal Tax Bracket	34%	39.3%	40%
Financing	50% equity; 50% debt with 6% interest	50% equity; 50% debt with 7% interest	30% debt with 8% interest rate; 50% tax equity at 8.5% cost; 20% common equity at 12% cost
Location	Raleigh, NC	Unknown	Southwest
Levelized Cost of Energy of Solar PV	$0.09/kWh in 2011	$0.24 - $0.46/kWh in 2015	$0.09 - $0.19/kWh in 2011

[17] Inwood, S. (2011, June). *Program on Technology Innovation: Integrated Generation Technology Options.* Electric Power Research Institute. Available at http://my.epri.com/portal/server.pt?Abstract_id=000000000001022782 [January 23, 2012]
[18] Lazard. (2011, June). Levelized Cost of Energy Analysis - Version 5.

APPENDIX B: TABLES OF GRID PARITY SCENERIOS

Table 9. ***Scenario 1 - LCOE of Solar PV Systems 10 kW or Less and Cooperative Residential Electricity Prices.***

Year	High Residential Retail Price ($/MWh)	Median Residential Retail Price ($/MWh)	Low Residential Retail Price ($/MWh)	Levelized Cost of Energy ($/MWh)		Electric Customers at Grid Parity	
				With Tax Credits	Without Tax Credits	With Tax Credits	Without Tax Credits
2006	132	110	83	253	407	0	0
2007	139	114	84	292	459	0	0
2008	134	113	94	250	403	0	0
2009	168	121	98	228	374	0	0
2010	140	116	93	196	321	0	0
2011	143	125	101	189	309	0	0
2012	147	128	104	179	292	0	0
2013	153	132	108	167	273	0	0
2014	159	135	111	156	255	25,070	0
2015	165	138	115	146	239	113,926	0
2016	171	141	118	136	223	384,916	0
2017	177	145	122	128	209	614,503	0
2018	183	148	126	120	197	926,860	0
2019	189	151	128	113	184	926,860	524
2020	195	155	131	106	174	926,860	75,142

Note: Data is presented in $/MWh instead of $/kWh which is used in other sections of this report.

Table 10. ***Scenario 2 - LCOE of Solar PV Systems 10 kW or Less and Municipal Residential Electricity Prices.***

Year	High Residential Retail Price ($/MWh)	Median Residential Retail Price ($/MWh)	Low Residential Retail Price ($/MWh)	Levelized Cost of Energy ($/MWh)		Electric Customers at Grid Parity	
				With Tax Credits	Without Tax Credits	With Tax Credits	Without Tax Credits
2006	138	105	79	253	407	0	0
2007	135	108	67	292	459	0	0
2008	150	119	78	250	403	0	0
2009	179	126	83	228	374	0	0
2010	186	124	87	196	321	0	0
2011	179	128	83	189	309	0	0
2012	186	130	84	179	292	33,338	0
2013	193	133	84	167	273	65,532	0
2014	200	136	85	156	255	174,924	0
2015	206	139	85	146	239	227,692	0
2016	213	144	86	136	223	254,205	0
2017	220	149	86	128	209	346,212	33,338
2018	227	152	87	120	197	390,723	65,532
2019	234	156	87	113	184	427,001	148,518
2020	241	159	88	106	174	466,421	211,100

Note: Data is presented in $/MWh instead of $/kWh which is used in other sections of this report.

Table 11. ***Scenario 3 - LCOE of Solar PV Systems 10 kW or Less and Investor-Owned Residential Electricity Prices.***

Year	Duke Residential Retail Price ($/MWh)	Progress Residential Retail Price ($/MWh)	Dominion Residential Retail Price ($/MWh)	Levelized Cost of Energy ($/MWh)		Electric Customers at Grid Parity	
				With Tax Credits	Without Tax Credits	With Tax Credits	Without Tax Credits
2006	80	90	88	253	407	0	0
2007	82	94	93	292	459	0	0
2008	82	96	89	250	403	0	0
2009	84	104	99	228	374	0	0
2010	90	103	97	196	321	0	0
2011	88	106	98	189	309	0	0
2012	90	109	99	179	292	0	0
2013	91	112	101	167	273	0	0
2014	93	114	102	156	255	0	0
2015	94	117	104	146	239	0	0
2016	96	120	105	136	223	0	0
2017	97	123	107	128	209	0	0
2018	99	126	108	120	197	1,081,420	0
2019	100	129	110	113	184	1,081,420	0
2020	102	132	111	106	174	1,182,425	0

Note: Data is presented in $/MWh instead of $/kWh which is used in other sections of this report.

Table 12. ***Scenario 4 - LCOE of Solar PV Systems Greater than 10 kW through 500 kW and Cooperative Commercial Electricity Prices.***

Year	High Commercial Retail Price ($/MWh)	Median Commercial Retail Price ($/MWh)	Low Commercial Retail Price ($/MWh)	Levelized Cost of Energy ($/MWh)		Electric Customers at Grid Parity	
				With Tax Credits	Without Tax Credits	With Tax Credits	Without Tax Credits
2006	133	93	76	180	406	0	0
2007	167	96	76	198	445	0	0
2008	139	100	78	198	445	0	0
2009	146	106	86	159	358	0	0
2010	141	103	80	130	292	3,983	0
2011	144	106	85	120	270	8,734	0
2012	150	109	87	114	256	15,443	0
2013	157	112	90	104	233	47,139	0
2014	163	116	92	95	213	86,620	0
2015	169	119	95	87	195	88,543	0
2016	175	122	97	80	179	88,543	0
2017	182	124	100	73	164	88,543	3,983
2018	188	127	102	67	152	88,543	7,557
2019	194	130	105	62	141	88,543	17,959
2020	200	133	107	58	131	88,543	40,966

Note: Data is presented in $/MWh instead of $/kWh which is used in other sections of this report.

Table 13. ***Scenario 5 - LCOE of Solar PV Systems Greater than 10 kW through 500 kW and Municipal Commercial Electricity Prices.***

Year	High Commercial Retail Price ($/MWh)	Median Commercial Retail Price ($/MWh)	Low Commercial Retail Price ($/MWh)	Levelized Cost of Energy ($/MWh)		Electric Customers at Grid Parity	
				With Tax Credits	Without Tax Credits	With Tax Credits	Without Tax Credits
2006	180	93	53	180	406	0	0
2007	145	95	59	198	445	0	0
2008	156	98	60	198	445	0	0
2009	196	106	65	159	358	315	0
2010	200	109	66	130	292	11,436	0
2011	182	108	68	120	270	20,102	0
2012	191	110	68	114	256	24,479	0
2013	200	113	68	104	233	42,365	0
2014	208	115	68	95	213	44,116	0
2015	217	116	68	87	195	62,065	171
2016	225	119	69	80	179	85,652	392
2017	234	122	69	73	164	87,286	6,097
2018	243	126	69	67	152	89,284	19,042
2019	251	128	69	62	141	89,284	24,155
2020	260	131	69	58	131	89,284	34,186

Note: Data is presented in $/MWh instead of $/kWh which is used in other sections of this report.

Table 14. ***Scenario 6 - LCOE of Solar PV Systems Greater than 10 kW through 500 kW and Investor-Owned Commercial Electricity Prices.***

Year	Duke Commercial Retail Price ($/MWh)	Progress Commercial Retail Price ($/MWh)	Dominion Commercial Retail Price ($/MWh)	Levelized Cost of Energy ($/MWh)		Electric Customers at Grid Parity	
				With Tax Credits	Without Tax Credits	With Tax Credits	Without Tax Credits
2006	64	73	73	180	406	0	0
2007	66	77	78	198	445	0	0
2008	66	79	75	198	445	0	0
2009	68	86	84	159	358	0	0
2010	72	86	83	130	292	0	0
2011	70	85	82	120	270	0	0
2012	71	88	84	114	256	0	0
2013	72	90	86	104	233	0	0
2014	74	93	88	95	213	0	0
2015	75	96	90	87	195	204,817	0
2016	77	98	91	80	179	204,817	0
2017	78	101	93	73	164	464,754	0
2018	79	104	95	67	152	464,754	0
2019	81	106	97	62	141	464,754	0
2020	82	109	98	58	131	464,754	0

Note: Data is presented in $/MWh instead of $/kWh which is used in other sections of this report.

Table 15. ***Scenario 7 - LCOE of Solar PV Systems Greater than 500 kW and Cooperative Commercial Electricity Prices.***

Year	High Commercial Retail Price ($/MWh)	Median Commercial Retail Price ($/MWh)	Low Commercial Retail Price ($/MWh)	Levelized Cost of Energy ($/MWh)		Electric Customers at Grid Parity	
				With Tax Credits	Without Tax Credits	With Tax Credits	Without Tax Credits
2006	133	93	76	-	-	-	-
2007	167	96	76	-	-	-	-
2008	139	100	78	-	-	-	-
2009	146	106	86	-	-	-	-
2010	141	103	80	104	235	36,178	0
2011	144	106	85	94	211	64,556	0
2012	150	109	87	85	190	88,543	0
2013	157	112	90	76	172	88,543	0
2014	163	116	92	69	156	88,543	152
2015	169	119	95	63	142	88,543	7,557
2016	175	122	97	58	130	88,543	15,443
2017	182	124	100	53	120	88,543	43,074
2018	188	127	102	49	111	88,543	78,876
2019	194	130	105	46	103	88,543	88,543
2020	200	133	107	43	96	88,543	88,543

Note: Data is presented in $/MWh instead of $/kWh which is used in other sections of this report.

Table 16. ***Scenario 8 - LCOE of Solar PV Systems Greater than 500 kW and Municipal Commercial Electricity Prices.***

Year	High Commercial Retail Price ($/MWh)	Median Commercial Retail Price ($/MWh)	Low Commercial Retail Price ($/MWh)	Levelized Cost of Energy ($/MWh)		Electric Customers at Grid Parity	
				With Tax Credits	Without Tax Credits	With Tax Credits	Without Tax Credits
2006	180	93	53	-	-	-	-
2007	145	95	59	-	-	-	-
2008	156	98	60	-	-	-	-
2009	196	106	65	-	-	-	-
2010	200	109	66	104	235	38,712	0
2011	182	108	68	94	211	43,302	0
2012	191	110	68	85	190	60,651	61
2013	200	113	68	76	172	85,652	199
2014	208	115	68	69	156	87,286	544
2015	217	116	68	63	142	89,284	17,087
2016	225	119	69	58	130	89,284	24,231
2017	234	122	69	53	120	89,284	33,637
2018	243	126	69	49	111	89,284	42,446
2019	251	128	69	46	103	89,284	46,436
2020	260	131	69	43	96	89,284	56,756

Note: Data is presented in $/MWh instead of $/kWh which is used in other sections of this report.

Table 17. ***Scenario 9 - LCOE of Solar PV Systems Greater than 500 kW and Investor-Owned Commercial Electricity Prices.***

Year	Duke Commercial Retail Price ($/MWh)	Progress Commercial Retail Price ($/MWh)	Dominion Commercial Retail Price ($/MWh)	Levelized Cost of Energy ($/MWh)		Electric Customers at Grid Parity	
				With Tax Credits	Without Tax Credits	With Tax Credits	Without Tax Credits
2006	64	73	73	-	-	-	-
2007	66	77	78	-	-	-	-
2008	66	79	75	-	-	-	-
2009	68	86	84	-	-	-	-
2010	72	86	83	104	235	0	0
2011	70	85	82	94	211	0	0
2012	71	88	84	85	190	187,159	0
2013	72	90	86	76	172	204,817	0
2014	74	93	88	69	156	464,754	0
2015	75	96	90	63	142	464,754	0
2016	77	98	91	58	130	464,754	0
2017	78	101	93	53	120	464,754	0
2018	79	104	95	49	111	464,754	0
2019	81	106	97	46	103	464,754	187,159
2020	82	109	98	43	96	464,754	204,817

Note: Data is presented in $/MWh instead of $/kWh which is used in other sections of this report.

APPENDIX C: GRAPHS OF GRID PARITY SCENERIOS

Figure 5. ***Scenario 1 - LCOE of Solar PV Systems 10 kW or Less and Cooperative Residential Electricity Prices.***

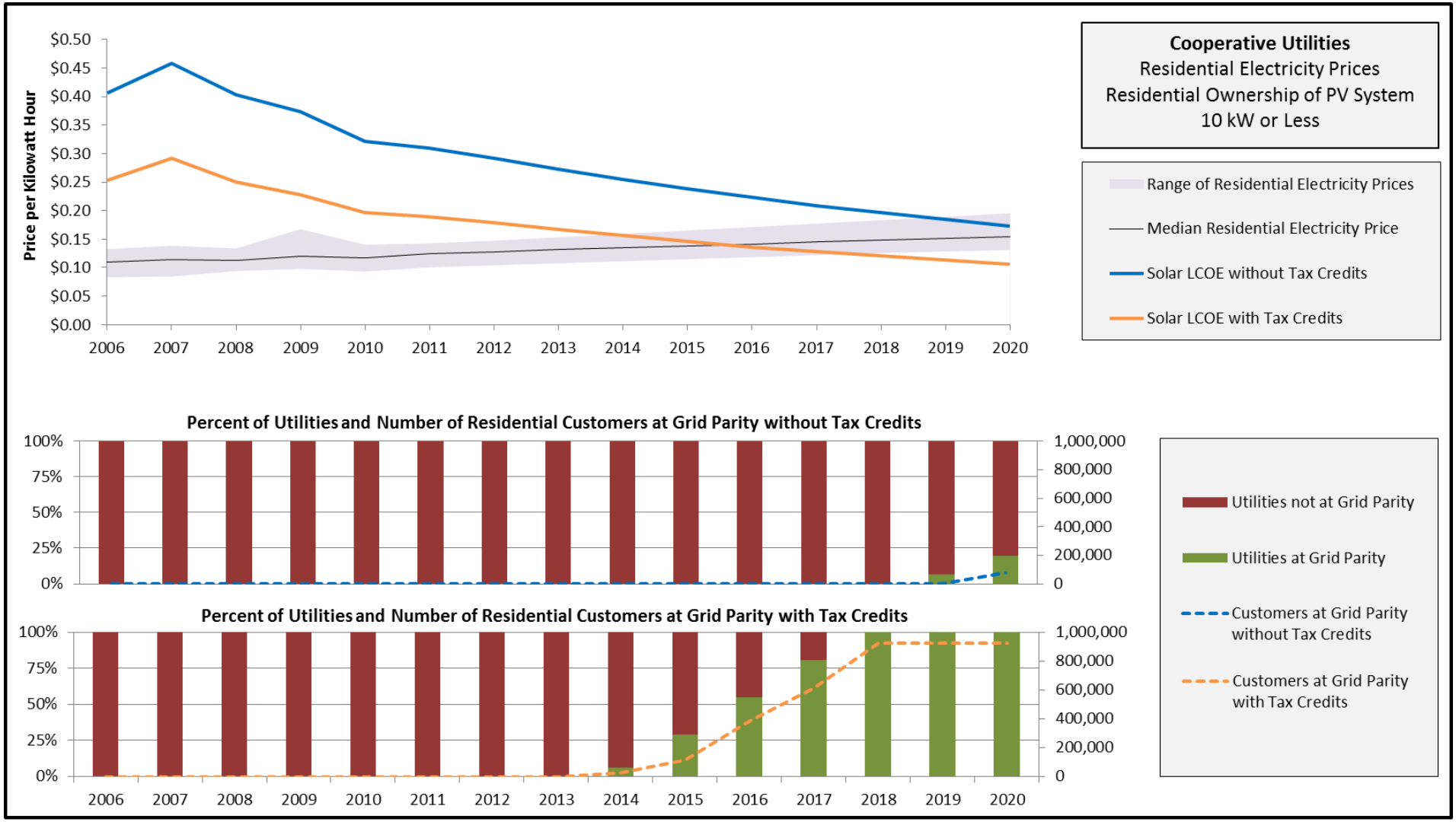


Figure 6. ***Scenario 2 - LCOE of Solar PV Systems 10 kW or Less and Municipal Residential Electricity Prices.***

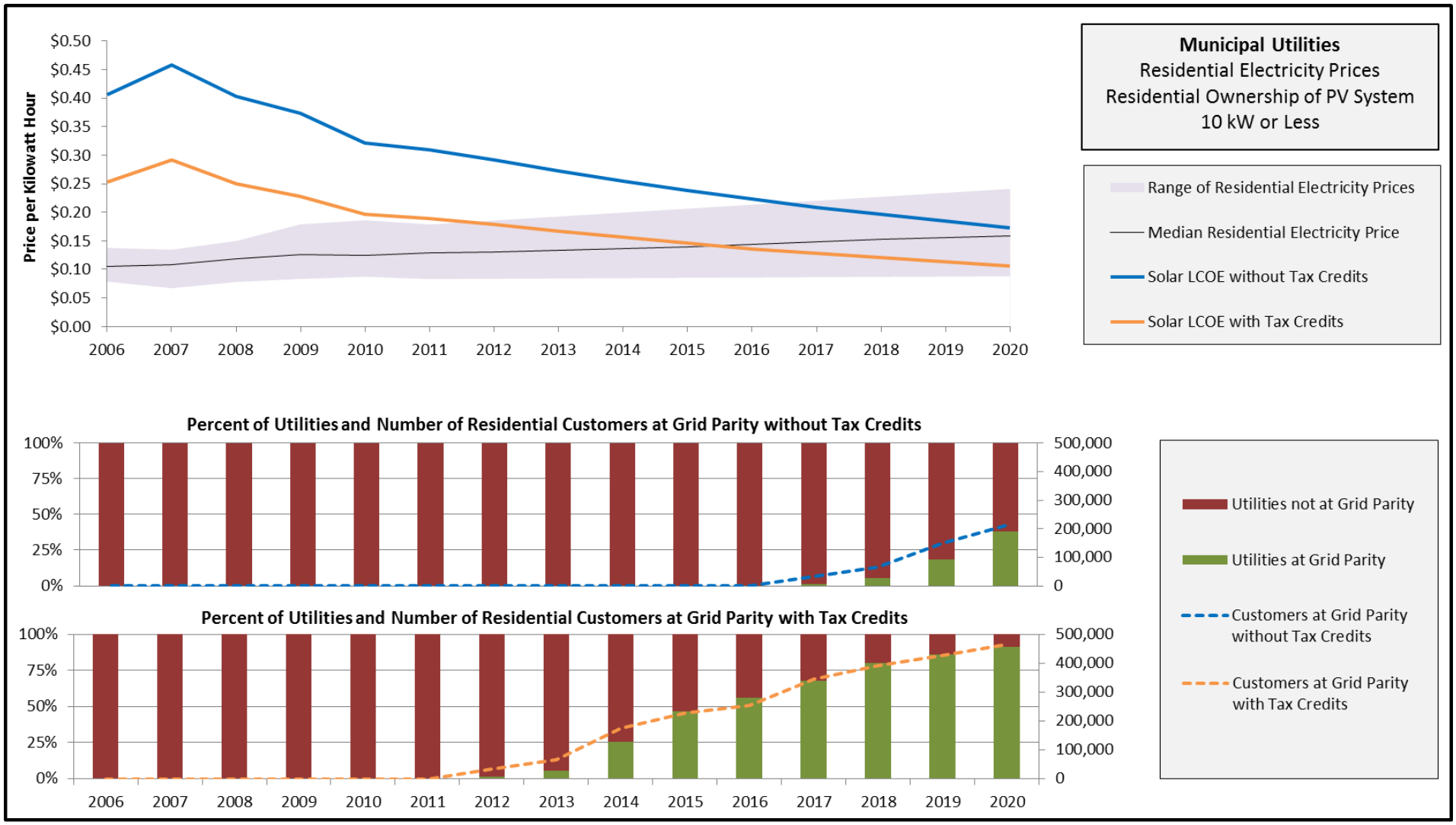


Figure 7. ***Scenario 3 - LCOE of Solar PV Systems 10 kW or Less and Investor-Owned Residential Electricity Prices.***

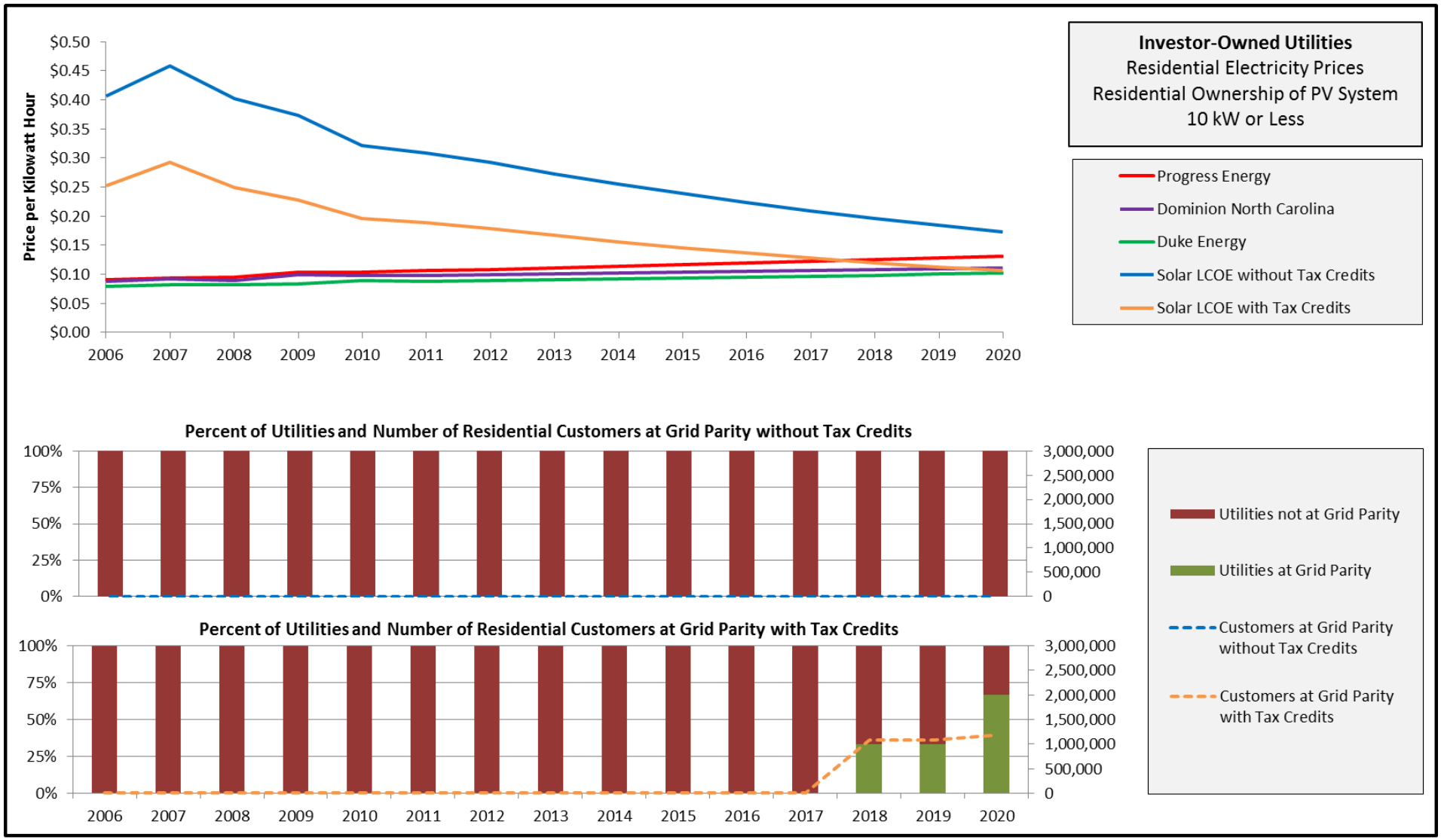


Figure 8. ***Scenario 4 - LCOE of Solar PV Systems Greater than 10 kW through 500 kW and Cooperative Commercial Electricity Prices.***

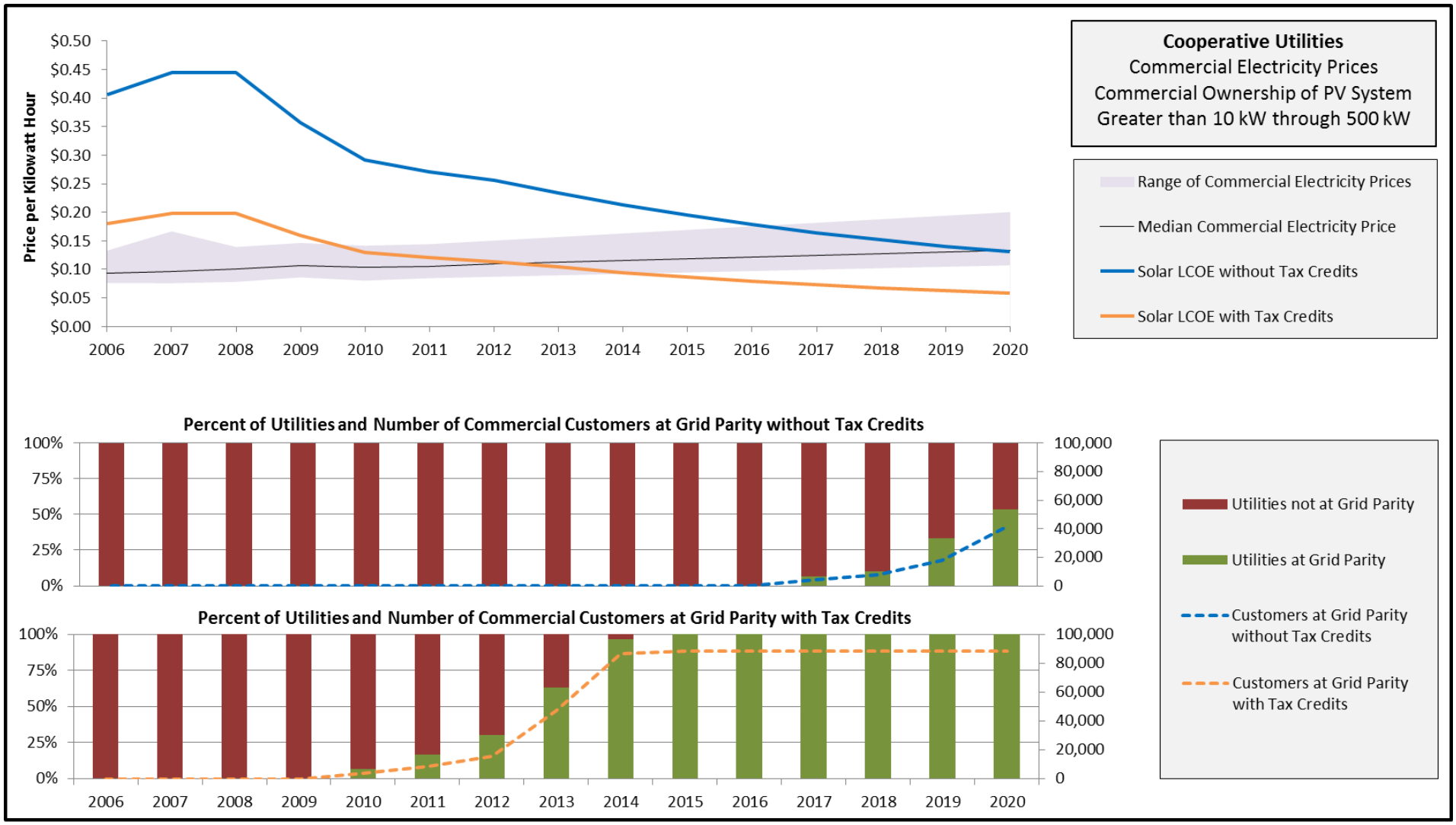


Figure 9. ***Scenario 5 - LCOE of Solar PV Systems Greater than 10 kW through 500 kW and Municipal Commercial Electricity Prices.***

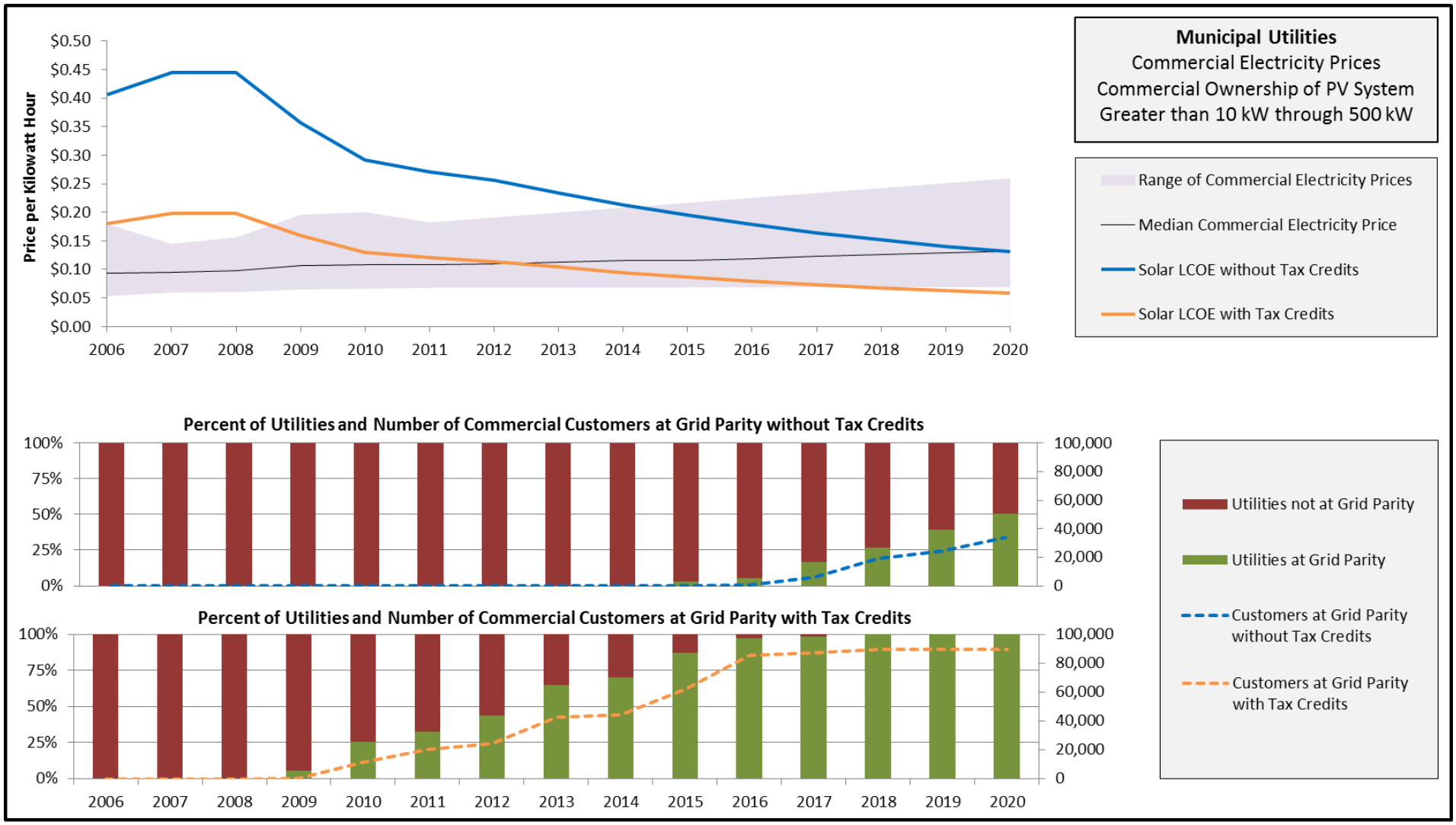


Figure 10. ***Scenario 6 - LCOE of Solar PV Systems Greater than 10 kW through 500 kW and Investor-Owned Commercial Electricity Prices.***

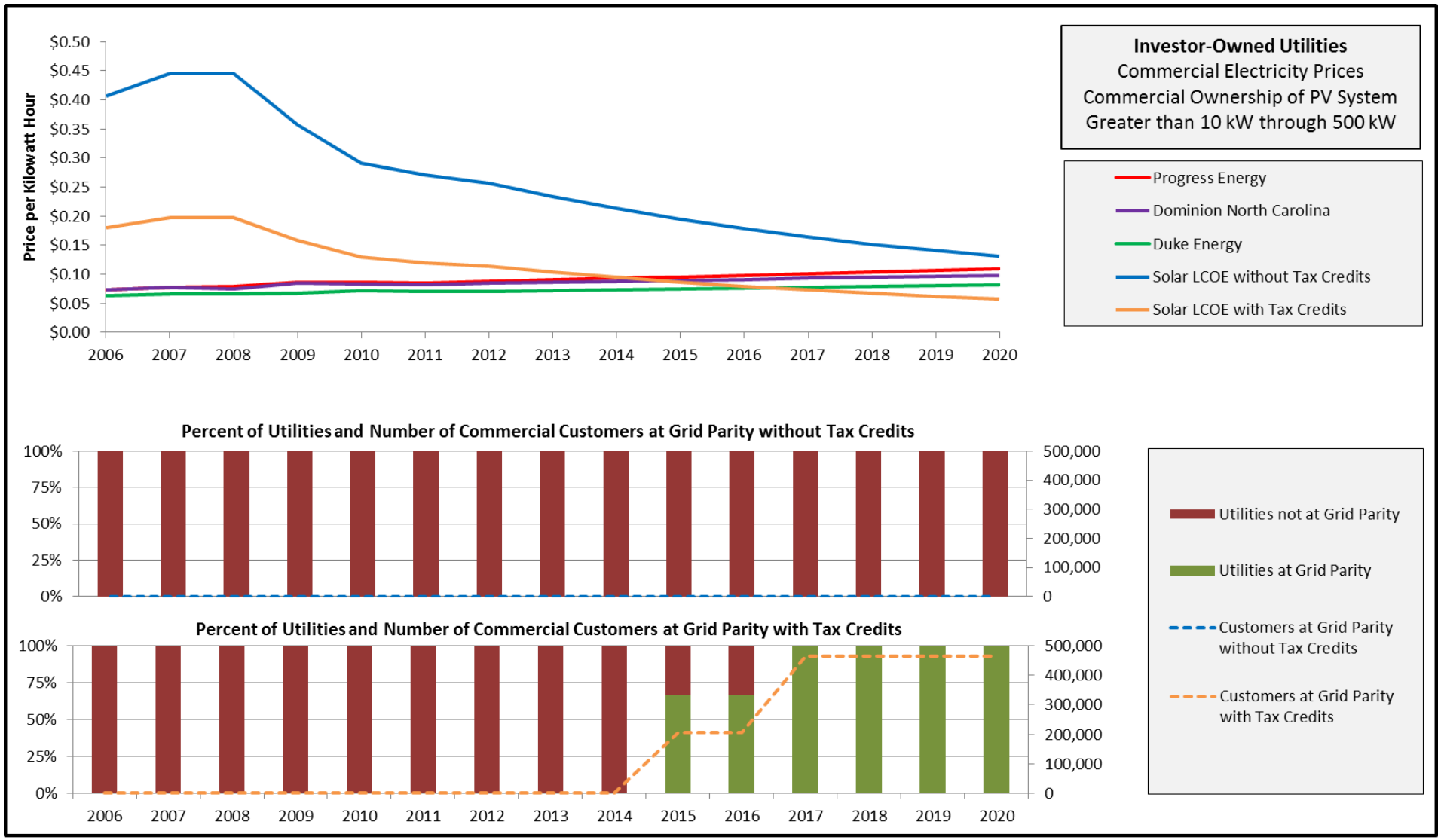


Figure 11. ***Scenario 7 - LCOE of Solar PV Systems Greater than 500 kW and Cooperative Commercial Electricity Prices.***

Figure 12. ***Scenario 8 - LCOE of Solar PV Systems Greater than 500 kW and Municipal Commercial Electricity Prices.***

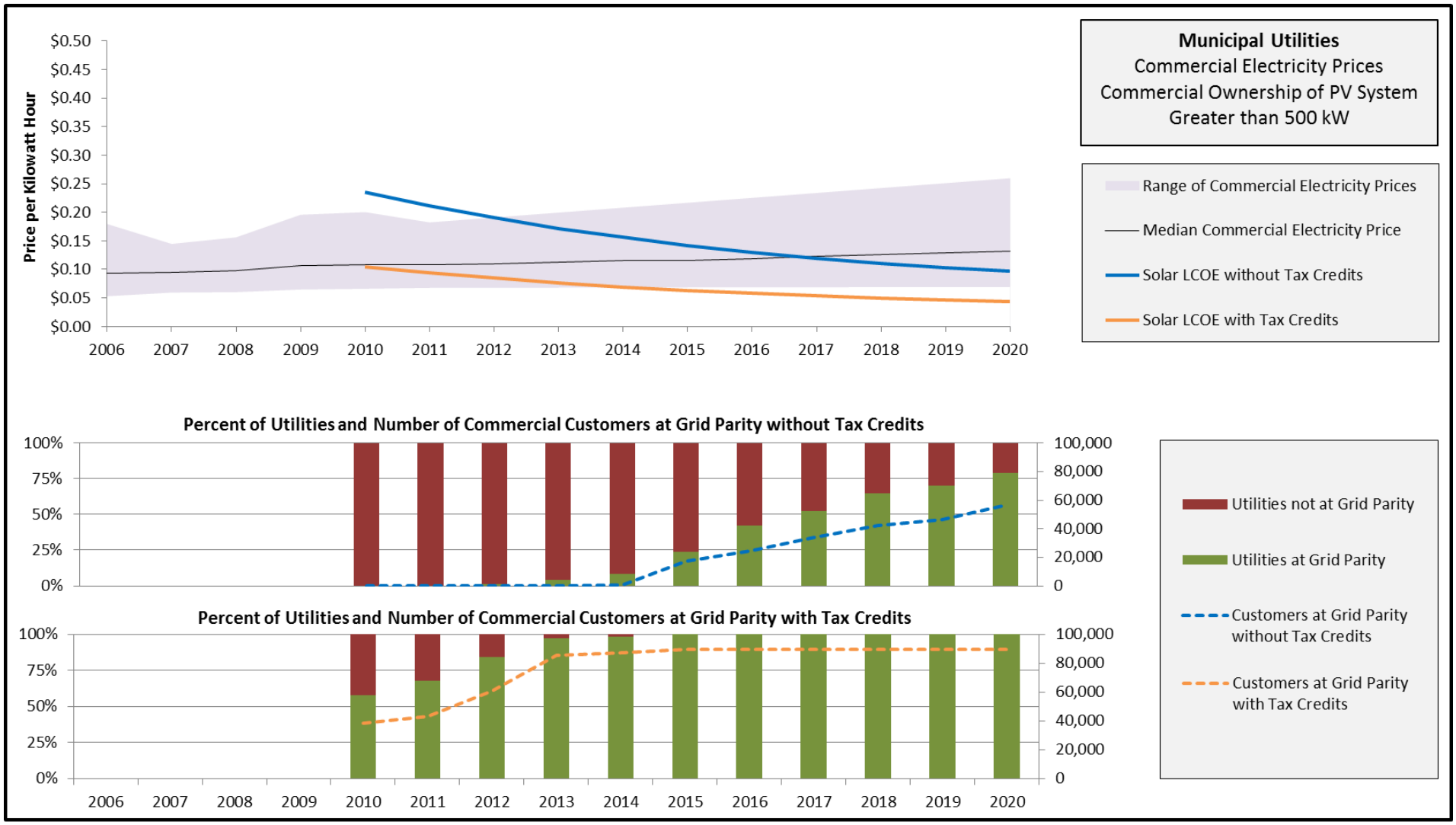


Figure 13. ***Scenario 9 - LCOE of Solar PV Systems Greater than 500 kW and Investor-Owned Commercial Electricity Prices.***