Applied Economics Clinic
Economic and Policy Analysis of Energy, Environment and Equity

SOMMER ENERGY, LLC

Pennsylvania Long-Term Renewables Contracts Benefits and Costs

Prepared on behalf of the Mid-Atlantic Renewable Energy Coalition

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Executive Summary

On behalf of the Mid-Atlantic Renewable Energy Coalition, the Applied Economics Clinic and Sommer Energy, LLC compared the expected cost of two methods of buying renewable energy and alternative energy credits (AECs) equivalent to one-half of Pennsylvania's incremental Alternative Energy Portfolio Standard (AEPS):

1) Continued purchase of AECs and energy at six-month procurement auctions, and

2) Long-term (10 or 20 year) purchase power agreements (PPAs) for wind and solar energy.

We found that using long-term contracts (PPAs) to purchase renewables saves money for electric consumers.

Over a ten-year period, 20-year PPA contracts for one-half of Pennsylvania's incremental AEPS requirement would save ratepayers $134 to $331 million. Twenty-year PPA contracts were less expensive than auction purchases under any natural gas price scenario, while 10-year contracts were less expensive than auction purchases under a high natural gas price future.

Net present value difference between PPA and auction costs (millions of 2016$)

		Natural Gas Price Projection		
		Low	Base	High
1/2 Total AEPS	10-year	$85	$18	($112)
	20-year	($134)	($201)	($331)

These savings estimates do not account for long-term PPA contracts' potential to lower spot-market AEC prices. Instead, savings are a result of differences in the price of renewable energy depending on whether it is purchased at auction or via contract.

The results of our study are in line with a broader literature that documents benefits to consumers from long-term renewables contracts. Studies on long-term contracting for renewable energy have shown benefits that include:

- Incentives for renewable development, by providing predictable revenue streams to renewable energy developers that helps to secure financing and lower financing costs;
- Price stability, by locking in rates over multi-year timeframes which protects customers from rate adjustments during unstable market periods;
- Lower Renewable Energy Certificate (REC) prices, by adding renewable generators and increasing the availability of RECs;
- Lower energy costs, by replacing expensive-to-run resources like coal with inexpensive-to-run resources like wind and solar in the generation supply;
- Economic development through new jobs from renewable construction and operation; and
- Reduced air pollution, by displacing fossil-fuel generators with non-emitting renewables, which has significant health benefits for consumers.

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I. Introduction

The cost of renewable energy to consumers depends in part on the way in which default service provider (DSP) and electric generation suppliers purchase that energy. Some contractual arrangements for renewable energy purchases result in lower costs than others. This study examines the potential benefits of longer term contracting for the renewables needed to meet Pennsylvania's Alternative Energy Portfolio Standard (AEPS).

Pennsylvania's 2004 Alternative Energy Portfolio Standards Act requires the Commonwealth's electric distribution companies (EDC) to purchase Tier I alternative energy credits (AEC) equal to 6 percent of their retail sales by 2017, rising to 8 percent in 2021. At present, Pennsylvania EDCs purchase renewable generation and the "AECs" associated with it at procurement auctions every six months. Analysis by Applied Economics Clinic and Sommer Energy, LLC on behalf of the Mid-Atlantic Renewable Energy Coalition compared the expected cost of buying renewable energy and AECs equivalent to one-half of Pennsylvania's incremental AEPS requirement for its total electric sales (that is, half of the increase to the AEPS each year starting in 2018) in two ways:

- Continued purchase at six-month procurement auctions
- Long-term (10 or 20 year) purchase power agreements (PPAs) for wind and solar energy

Studies of long-term contracts in Maryland, Massachusetts, New Jersey and New York found benefits to consumers including price stability, added incentive to renewable development, lower renewable energy certificate[1] prices, lower energy costs, economic development, and reduced air pollution.

The analysis presented here supports these findings: Using long-term contracts to purchase renewables saves money for electric consumers. Over a ten-year period, we found that 20-year PPA contracts for one-half of Pennsylvania's incremental AEPS requirement would save ratepayers $134 to $331 million.

The subsequent sections of this report present our analysis in detail. Section II reviews our study's findings and discusses potential sources of price savings for consumers from renewable purchases. Section III provides a summary of existing literature regarding potential consumer benefits from long-term contracts for renewables. Section IV presents our policy recommendation that long-term contracts for renewable purchases are in the public interest and should be required of Pennsylvania's EDCs. Appendix A to our report includes a description of methods, assumptions and data, and Appendix B contains a list of questions asked of Mid-Atlantic Renewable Energy Coalition members in an anonymous survey used to inform assumptions regarding renewable PPA costs and financing in this study.

[1] Renewable Energy Certificates are a generic term referring the tradable instrument used for renewable portfolio standard compliance such as the Pennsylvania Alternative Energy Portfolio Standard. In Pennsylvania RECs are commonly referred to AECs (Alternative Energy Credits). The terms may be used interchangeably in this report.

II. Study Findings

We estimated the cost of two different methods of purchasing enough renewable energy and associated AECs to satisfy one-half of the future increases in Pennsylvania AEPS Tier I requirement for its total electric sales:

1. Six-month procurement auctions (the status quo) with consideration of the sensitivity of auction prices to the price of natural gas:
2. Long-term (10 or 20 year) purchase power agreements (PPAs) for either wind or solar energy

We compared the status quo auction purchasing to costs under long-term PPA contracts. The difference between the PPA prices and the procurement auction prices is the per kilowatt-hour (kWh) benefit of procuring renewables through long-term contracts. The dollar value for this benefit is the product of the amount of energy purchased in kWhs and the $/kWh benefit. The amount of renewables and AECs procured is the same in all scenarios examined, regardless of natural gas price, length of contract, and whether the purchase is through a PPA contract or an auction. (A detailed methodology for this analysis is presented in Appendix A of this report.)

Using this method we found that:

- Long-term contracts are always less expensive than auction purchases under a high natural gas price future. Under a low or base natural gas price future the economics of long-term contracts depends on their length: Longer contracts are more economic.
- Long-term contracts are always less expensive than auction purchases when contracted as 20-year PPAs. When contracted as 10-year PPAs the economics of long-term contracts depends on the price of natural gas: The contracts are more economic when gas prices are high.

Table 1 and Figure 1 show these summary results on a cumulative and annual basis, respectively. Negative (red) prices represent savings to consumers.

Table 1. Net present value difference between PPA and auction costs (millions of 2016$)

		Natural Gas Price Projection		
		Low	Base	High
1/2 Total AEPS	10-year	$85	$18	($112)
	20-year	($134)	($201)	($331)

Table 1 compares cumulative costs over the 2018 to 2027 period after adjusting for inflation (this adjustment is called “net present value”) and the cost of capital.[2] Each cell records the difference in net present value between (a) the cost of procuring renewable energy and AECs via PPA

[2] A 5.1 percent real discount rate is used throughout this analysis.

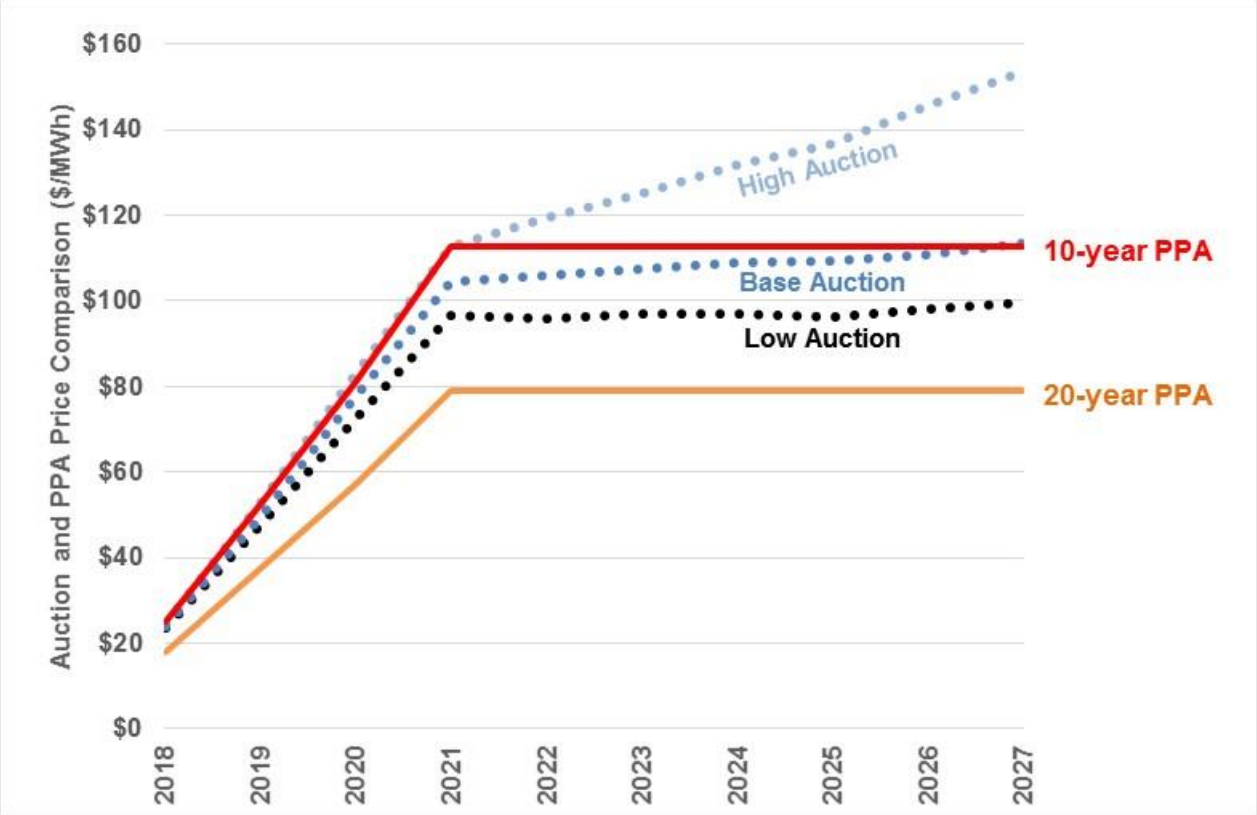
contracts and (b) the cost of procuring the same energy and AECs via auction. Purchasing one-half of Pennsylvania's incremental renewable needs using 20-year PPA contracts would save ratepayers $134 to $331 million, depending on the future price of natural gas.

Using 10-year PPA contracts would be more expensive than auction purchases under low and base natural gas price expectations, but would save ratepayers $112 million if natural gas prices are at the high end of their expected range. PPA contracts of lengths in between 10 and 20 years were not examined in this analysis. We expect that net benefits to consumers of 15-year PPA contracts would fall somewhere in between the results of 10- and 20-year PPAs, and that 15-year PPAs would always be economic under high gas prices and likely also be economic under a base gas price future.

Figure 1 shows the annual costs of the PPA and auction purchases themselves (and not the difference between the two). The annual costs of the 10-year PPA contracts are within the range of the auction costs. The costs of meeting one-half Pennsylvania's incremental renewable energy needs using 20-year PPAs are below that of the auction costs, even at the lowest natural gas price predictions.[3]

[3] Modeling in this report assumes a simplified six-month timescale for procurement auctions. Actual Pennsylvania procurement occurs for varying delivery periods ranging from 3 to 24 months depending on the utility and customer sector in question.

Figure 1. Annual purchase costs via PPA and auction (million 2016$)



Our estimates include just one of the two most direct expected impacts of long-term contracts for renewable purchases:

- **Lower renewable energy costs are included:** Auction purchase costs depend on the costs of operating the marginal unit (the last generating unit to be called to run based on relative prices in PJM (Pennsylvania's electric supply region), which is a natural gas generator in most hours of the year), future additions and retirements of generating units, and uncertain expectations about the price of natural gas. In contrast, PPA contracts for renewables depend on the expected cost of financing, constructing, and operating wind and solar generation, and the length of the contracting period. Our analysis focused on the differences in these resulting costs.
- **Lower AECs prices are not included:** Long-term contracts for renewables may also result in lower AEC prices, an additional benefit to ratepayers. While our study did not attempt to estimate benefits from lower AEC prices, a 2015 study of the benefits of long-term contracting for compliance with New Jersey's Renewable Portfolio Standard (RPS) found that long-term PPA contracting drove New Jersey's Renewable Energy Certificate

(REC) prices down by 25 percent.[4] One important avenue by which long-term contracts may reduce REC or AEC prices is by providing incentives to invest in renewables. More renewables depress REC prices while a scarcity of renewables elevates REC prices.

The way in which the price of renewable energy is set and the change to the price of renewable certificates (AECs) are both critical potential benefits of long-term contracts as compared to auctions.

In addition, and distinctly, complying with AEPs—and thereby adding renewable generation in PJM—results in lower costs to consumers regardless of whether the renewables are bought at auction or via long-term contracts. This results from the addition of renewable energy in the wholesale market which increases low-cost energy supply and reduces wholesale energy prices. In competitive procurements auctions these costs savings may be passed on to consumers. This important impact on consumer costs can be expected from these renewable purchases but it is not modeled here because its effect would be identical using either PPA or auction purchases:

- **Lower wholesale energy costs:** Pennsylvania's AEPS lowers the wholesale price of energy and, therefore, the energy purchase costs that are passed along to ratepayers. Wind and solar resources are "must run", meaning that because of their low per kilowatt-hour costs they are called on to provide generation first before any other kind of generation. Adding inexpensive-to-run resources to the supply of generation in the larger Pennsylvania region means that more expensive resources are called on to run less, and the total cost of electricity supply falls. (These cost savings are generally expected to be greater than any capacity or ancillary service cost increases associated with additional renewables on the system.)[5]

Table 2 (below) presents a complete set of results from our analysis, again showing the net present value of cumulative costs over the 2018 to 2017 period. The top grouping of results shows PPA contract costs, which do not vary based on natural gas price projections. The second grouping shows auction costs, which do not vary based on contract length. The final grouping shows the difference between the two: PPA costs less auction costs.

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[4] Sustainable Energy Advantage. 2015. Potential Benefits of Long-Term Contracts for RPS Compliance in New Jersey. Prepared for the Mid-Atlantic Renewable Energy Coalition. Table 1.

[5] See also Wiser et al. (2017) *Impacts of Variable Renewable Energy on Bulk Power System Assets, Pricing, and Costs.* Berkeley Lab: Electricity Markets & Policy Group. https://emp.lbl.gov/publications/impacts-variable-renewable-energy/?utm_source=newsletter88&utm_medium=email&utm_campaign=Constant%20Contact&utm_source=Wiser-Impact+and+Drivers+reports&utm_campaign=Wiser-Impact+and+Drivers+reports&utm_medium=email

Table 2. Net present value of wind and solar PPA and auction costs (millions of 2016$)

PPA Cost (millions of 2016$)				
		Natural Gas Price Projection		
		Low	Base	High
1/2 Wind AEPS	10-year	$647		
	20-year	$459		
1/2 Solar AEPS	10-year	$90		
	20-year	$60		
1/2 Total AEPS	10-year	$738		
	20-year	$519		

Auction Cost (millions of 2016$)				
		Natural Gas Price Projection		
		Low	Base	High
1/2 Wind AEPS	10-year	$570	$627	$735
	20-year			
1/2 Solar AEPS	10-year	$83	$93	$115
	20-year			
1/2 Total AEPS	10-year	$653	$720	$850
	20-year			

Difference: PPA Cost less Auction Cost (millions of 2016$)				
		Natural Gas Price Projection		
		Low	Base	High
1/2 Wind AEPS	10-year	$77	$21	($87)
	20-year	($111)	($168)	($276)
1/2 Solar AEPS	10-year	$8	($3)	($25)
	20-year	($22)	($33)	($55)
1/2 Total AEPS	10-year	$85	$18	($112)
	20-year	($134)	($201)	($331)

Pennsylvania's AEPS requires much less solar generation than it does generic Tier I (typically

wind) generation, which helps explain the higher costs for wind purchases using both PPA and auction purchasing. Required wind and solar purchases are summed together in the "1/2 Total AEPS" result, which provides enough renewable energy and AECs to supply one-half of Pennsylvania's additional AEPS requirement for ten years starting in 2018.

Our analysis focuses on the impacts of changing the purchasing method of one-half of Pennsylvania's incremental AEPS obligation. Overall, we find that long-term contracts can lower consumer costs. The underlying market forces that determine these results, however, do not depend on the specific amount of renewables purchased in long-term contracts. In principal, we would expect direction of our results—contracts save money, especially with longer contracts and when gas prices are high—to hold for both higher and lower amounts of renewable contracts.

III. Review of Existing Studies on Long-Term Renewables Contracts

Evidence from other jurisdictions supports the use of long-term contracts for the acquisition of renewable resources to meet RPS requirements. This section discusses analysis of actual and proposed long-term renewables contracts in Maryland, Massachusetts, New Jersey, and New York.

In recent years, the price of natural gas has been the primary influence on wholesale energy markets, keeping energy prices low and reducing revenues to all generators. Analysis by the Brattle Group demonstrates that new renewable generators have difficulty financing their projects due to low expected energy revenues and relatively small capacity payments that are not sufficient to cover their costs.[6] Long-term contractual agreements for renewable energy between project developers and electric utilities or local distribution companies provide predictable revenue streams to developers, who tend to be smaller entities lacking ready access to the capital necessary to construct renewable projects. A steady, predictable revenue stream helps project developers secure financing from lenders, making possible the construction of the new renewable generation resources needed to meet state mandates for renewables. According to the Brattle Group study, "[W]ith increased price certainty for a project, investors require a lower return, which in turn reduces the cost of financing for the project, when compared with a project that relies purely on spot market dynamics for revenues."[7] Long-term contracts help renewable projects get built, often at a lower cost.

Long-term contracts themselves, as well as the resulting increase in renewable generation, benefit consumers in RPS states:

- **Price stability:** Long-term contracts for renewable energy can offer price stability over a multi-year timeframe. Customers are protected from constant rate adjustments during periods when energy and capacity markets are unstable.
- **Incentive to renewable development:** Long-term contracts encourage the development of new renewable generation resources by offering increased price certainty and lower financing costs.
- **Lower REC prices:** The addition of renewable generators leads to an increase in the availability of RECs. An increase in the supply of RECs helps to lower the price, which in turn reduces the cost of meeting the RPS and benefits ratepayers.
- **Lower energy costs:** The addition of renewable generation to the wholesale market supply curve displaces the most expensive generating units and lowers the wholesale

[6] Weiss, Jurgen, and Mark Sarro. 2013. The Importance of Long-term Contracting for Facilitating Renewable Energy Project Development. The Brattle Group. Page 7. http://www.brattle.com/system/publications/pdfs/000/004/927/original/The_Importance_of_Long-Term_Contracting_for_Facilitating_Renewable_Energy_Project_Development_Weiss_Sarro_May_7_2013.pdf?1380317003

[7] Brattle Group. Page 12.

market price of energy.

- **Economic development:** In-state development of renewables adds jobs and economic development.
- **Reduced air pollution:** Displacement of fossil-fired generators with non-emitting renewables leads to a reduction in air emissions and a corresponding increase in health benefits for consumers.

These benefits are discussed in more detail in the state-specific examples below.

Maryland

Long-term contracting for renewable generating resources was proposed by Levitan & Associates in a study prepared for the state of Maryland on the options available to the state to restore its influence over electric rates and new generation construction following electricity market restructuring. The study's authors noted that state RPS and other environmental requirements "have made renewable generation resources and demand response more significant components of states' energy plans, but existing competitive markets have proven ill-suited to their development."[8] They found that, at the time of the study, wholesale markets encouraged generation owners to maintain the status quo and rewarded persistent capacity shortages, which resulted in higher wholesale prices and jeopardized reliability.[9] Levitan & Associates proposed strategic long-term contracts as a solution that would reduce both wholesale market prices and capacity prices, improve reliability, and achieve state environmental goals.

Long-term contracting was emphasized as an action that Maryland could take that would allow it the flexibility to tailor resource procurement in a way that met state needs. Contracts that emphasized renewable resources would both diversify Maryland's fuel mix and lower energy and capacity charges in the state through the addition of lower-cost resources in areas where prices were highest. Low cost renewable resources would displace the more expensive fossil-fired units that were setting high wholesale prices during peak periods, resulting in lower Locational Marginal Prices (LMPs) at energy price nodes and leading to lower and more stable retail prices for consumers over time.[10]

Massachusetts

In 2008, electric distribution companies in Massachusetts were required to begin executing long-term PPAs for energy and/or RECs with renewable developers for a term of 10 to 15 years under

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[8] Levitan & Associates. 2007. State Analysis and Survey on Restructuring and Reregulation. Prepared for Maryland Public Service Commission. Page 1. http://www.psc.state.md.us/wp-content/uploads/KayeScholer_State-Analysis-and-Survey-on-Restructuring-and-Re-Regulation-_11.30.07.pdf

[9] Levitan & Associates. Page 75.

[10] Levitan & Associates. Page 81.

Section 83 of the Green Communities Act. A 2012 study by Peregrine Energy Group examined whether that long-term contracting requirement had met state goals by facilitating the development, financing, and construction of new renewable energy projects.[11] The Massachusetts Department of Public Utilities was responsible for approval of long-term contracts, and new projects were required to be cost effective to ratepayers, contribute to moderating peak loads, and provide enhanced electric reliability. Following passage of Section 83, five PPAs were executed between renewable project developers and distribution companies.[12] Renewable project developers stated that the PPAs "were critically important in their ability to finance and build their projects."[13]

The Peregrine study notes that one of the benefits of long-term contracting for renewables is that the projects resulting from those contracts increase the supply of Class 1 RECs needed to meet demand under the RPS, thereby reducing REC market prices. A shortage of RECs, conversely, would cause REC prices to move toward the Alternative Compliance Price, resulting in higher rates for customers.[14] An increase in the amount of renewable energy generation resulting from long-term contracts suppresses the wholesale price of energy; when zero or low variable cost resources are added to the supply curve, the wholesale market clearing price falls in many hours of the year.[15]

New Jersey

A 2015 study by Sustainable Energy Advantage examined the potential benefits of using long-term contracts to meet 50 percent of New Jersey's incremental RPS obligation between 2017 and 2025, compared to purchasing 100 percent of required RECs on the spot market.[16] Sustainable Energy Advantage found that the presence of long-term contracts leads to an increased ability to finance new renewable energy facilities, which lowers energy costs, REC prices, and costs to ratepayers.[17] The cost savings associated with meeting 50 percent of incremental RPS obligations

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[11] Peregrine Energy Group. 2012. Study on Long-Term Contracting Under Section 83 of the Green Communities Act. Prepared for the Massachusetts Department of Energy Resources. http://www.mass.gov/eea/docs/doer/pub-info/long-term-contracting-section-83-green-communitiesa-act.pdf

[12] Note that four of the five projects were constructed. The fifth, the offshore Cape Wind project, failed to meet contractual deadlines, causing the two distribution utilities with which it had entered a PPA to terminate their contracts.

[13] Peregrine Energy Group. 2012. Study on Long-Term Contracting Under Section 83 of the Green Communities Act. Prepared for the Massachusetts Department of Energy Resources. Page 4. http://www.mass.gov/eea/docs/doer/pub-info/long-term-contracting-section-83-green-communitiesa-act.pdf

[14] Peregrine. Page 35.

[15] Peregrine. Page 36.

[16] Sustainable Energy Advantage. 2015. Potential Benefits of Long-Term Contracts for RPS Compliance in New Jersey. Prepared for the Mid-Atlantic Renewable Energy Coalition.

[17] Sustainable Energy Advantage. Page 1.

through long-term contracting was estimated to be more than $600 million over the study period.[18]

Customers would realize savings on their electric bills as well. The study estimated ratepayer savings of approximately 50 cents per month compared to New Jersey's current procurement policies.[19] Sustainable Energy Advantage did not model a price suppression affect associated with renewable additions, and because these additions tend to reduce wholesale energy prices, their estimates of rate impacts are conservative.

New York

In 2013, the Brattle Group performed a study investigating the potential effect of long-term contracting on the development of renewable generating resources in New York. Evidence from previous years showed that most renewable energy projects in restructured U.S. power markets were built with the support of long-term contracts, and that there are important reasons that long-term contracts have been the dominant approach to support the development of renewable energy projects.[20] The study authors conclude that financing costs for renewable projects can be lowered as a result of the price certainty associated with bundled (energy, capacity, and RECs) long-term contracts over 15 to 20 years, and that the impact of lower financing costs could be materially beneficial to New York ratepayers. They estimate that contracts awarded between 2013 and 2015 to meet the remaining 2015 New York RPS commitment "could realistically range from $450 million to close to $1 billion" under simple examples and reasonable assumptions.[21] In addition to reducing the net retail price of electricity, the Brattle Group identified a number of other benefits to consumers associated with an increase in the amount of renewable generation in New York: 1) displacement of fossil-fired generation and reduction in air emissions, which reduces the cost of emission reductions needed from other parts of the economy; 2) creation of jobs and income associated with new facilities, as well as payments for land leases and purchases of materials and services; 3) a reduction in health impacts from air pollutants; and 4) a reduction in peak demand from increased solar generation, displacing more expensive peaking generation units, and possibly leading to a reduction in the need for new peaking capacity resources.

Similarly, the New York Department of Public Service (DPS), assisted by the New York State Energy Research and Development Authority (NYSERDA) issued a study examining the cost impact to consumers of meeting the state's Clean Energy Standard (CES), varying key input variables. One such variable was procurement structure— "bundled PPAs" versus "REC only"—to develop new renewables. Study findings show that bundled PPAs result in greater revenue certainty to developers, giving projects a lower expected gross program cost than a "REC only" procurement approach. Total benefits to consumers of the CES under a "REC only" scenario were

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[18] Sustainable Energy Advantage. Page 7.

[19] Sustainable Energy Advantage. Page 8.

[20] Weiss, Jurgen, and Mark Sarro. 2013. The Importance of Long-term Contracting for Facilitating Renewable Energy Project Development. The Brattle Group. Page 1.

[21] Brattle Group. Page 3.

estimated to be $65 million, compared to a benefit of more than $1.5 billion under a "PPA only" procurement scenario.[22]

Literature Review in Summary

Long-term contracting can play an important role in the financing and construction of new renewable generating projects in states that operate in a restructured market, particularly those that have a requirement for renewable energy under an alternative energy or renewable portfolio standard. Long-term contracts for renewables result in multiple benefits to consumers, including lower and more stable energy prices over time. They lead to economy-wide benefits in the form of job creation and economic development. Reductions in emissions from displaced fossil-fired generators result in health benefits to consumers and lessen the need for emission reductions from other sectors to meet policy goals, leading to additional consumer savings.

As noted in the Brattle Group's study of the impact of long-term renewable generation contracts, "(A)n important objective of public policy in regulating power markets is to promote and protect sunk investments in projects which benefit ratepayers but otherwise would not be undertaken."[23] The authors go on to say that given the shortcomings of wholesale markets, long-term contracts:

…are the most common practical tool for backing-up this policy objective with a meaningful degree of regulatory assurance… In the absence of the relative revenue certainty long-term contracts such as PPAs provide, it is difficult to envision investor willingness to finance any electric generation, especially renewable energy projects prone to uncertainty surrounding the RPS and how the current regulatory environment will evolve over the long-term. Entering into a PPA demonstrates a real commitment to getting a renewable project up and running economically.[24]

[22] New York State Department of Public Service. 2016. Clean Energy Standard White Paper – Cost Study. Slide 39.

[23] Brattle Group. Page 11.

[24] Brattle Group. Page 11.

IV. Policy Recommendations

Previous studies on long-term renewable energy contracting found important benefits to consumers and to the economy, including lower and more stable energy prices, job creation, economic development, and reduced air pollution and associated health benefits. Long-term contracts attract investment in renewables by providing a predictable revenue stream to developers, who may lack ready access to capital. A steady, predictable revenue stream helps project developers secure financing from lenders, making new renewable construction possible. Most importantly, long-term contracts reduce project developers' required returns through reduced risk, lowering overall project costs. These costs savings can be passed on to consumers in the form of lower REC prices.

Our analysis of the potential benefits of procuring half of the future, additional renewables required under Pennsylvania's AEPS found cost savings for electric consumers, particularly with longer term contracts. We found that purchasing one-half of Pennsylvania's incremental AEPS requirement for its total electric sales using 20-year PPA contracts saved electric consumers a total of $134 to $331 million from 2018 to 2027.

The substantial cost savings to customers from long-term PPA contracts are strengthened by the fact that our analysis did not account for potential cost savings from lower AEC prices. In addition, emissions reductions from displaced fossil-fired generators result in health benefits to consumers and lessen the need for emission reductions from other sectors to meet policy goals. Overall, our study provides evidence of the benefits that long-term contracting could make available to Pennsylvania electric consumers.

V. Appendix A: Methodology, Assumptions, and Data

We estimated the costs of procuring 50 percent of the renewable energy and AECs needed to comply with Pennsylvania's AEPS using two methods, and then compared these results:

1. **PPA Prices:** The bundled price of energy and AECs for 10- and 20-year power purchase agreements (PPA) (in $/kWh) in each year in the period 2018-2027.
2. **Procurement Auction Prices:** The price of energy purchased in Pennsylvania's power procurement auctions including the cost of capacity and auxiliary services and the price of AECs needed for AEPS compliance for that power (in $/kWh) in the period 2018-2027. We examined the sensitivity of these auction prices to variations in the expected price of natural gas.

The difference between the PPA price forecast and the procurement auction price forecast is the per kWh benefit (or cost) of procuring renewables through long-term contracts. A total dollar value of this benefit (or cost) is the product of the quantity of energy to be purchased in such contracts (for example, 50 percent of the AEPS requirement) and the $/kWh benefit.

Modeling PPA Prices

We forecasted PPA prices as a function of the following assumptions:

a. System size (MW)
b. System cost by year of installation ($/kW)
c. Expected capacity factor by year (%)
d. Book life (years)
e. State and federal tax rates (%)
f. Federal tax credits by year ($/MWh)
g. Share of financing by equity, debt, etc. (%)
h. Cost of equity, debt, etc. (%)
i. Debt period (years)
j. Depreciation schedule (years)

We used the results of an anonymous survey of MAREC members (attached as Appendix B of this report) to establish values for many of these assumptions. Other sources included the National Renewable Energy Lab's forecast of future renewable costs.[25] Table 3 presents our estimated prices for 10- and 20-year PPA contracts for wind and solar, along with key assumptions used to generate these PPA prices.

[25] http://www.nrel.gov/analysis/data_tech_baseline.html

Table 3. PPA price estimates and related assumptions

	Wind PPA			Solar PPA	
	10-year	20-year		10-year	20-year
Levelized Cost of Energy (LCOE) ($2016/MWh)			**Levelized Cost of Energy (LCOE) ($2016/MWh)**		
2018 Contract	$66.06	$47.61	**2018 Contract**	$91.22	$60.64
2019 Contract	$73.49	$52.23	**2019 Contract**	$89.67	$59.65
2020 Contract	$77.21	$54.54	**2020 Contract**	$90.83	$60.39
2021 Contract	$84.64	$59.16	**2021 Contract**	$93.54	$62.10
2022-2037 Contracts	$84.64	$59.16	**2022-2037 Contracts**	$101.67	$67.25
2018 PPA Assumptions			**2018 PPA Assumptions**		
Overnight Capital Cost ($2016/kw)	$1,400		**Overnight Capital Cost ($2016/kw)**	$1,350	
PTC ($2016/MWh)	$23.22		**ITC**	30%	
% of PTC Eligible	100%		**% of Capital Cost Eligible for ITC**	95%	
% of PTC Realized	80%		**% of ITC Realized**	80%	
Construction Period (years)	2		**Construction Period (years)**	1	
Capacity Factor	35%		**Capacity Factor**	22%	
Fixed O&M ($2016/kw-year)	$53		**Fixed O&M ($2016/kw-year)**	$14	
Variable O&M ($2016/MWh)	$0		**Variable O&M ($2016/MWh)**	$0	
Size (MW)	100		**Size (MW)**	50	
Annual Production (MWh)	306,600		**Annual Production (MWh)**	96,360	
Annual Degradation Factor	0%		**Annual Degradation Factor**	0.5%	
Inflation Rate	2%		**Inflation Rate**	2%	
Economic Lifetime (Years)	20		**Economic Lifetime (Years)**	20	
Calculated Interest Rate - Real	3%		**Calculated Interest Rate - Real**	3%	
Calculated Rate of Return on Equity - Real	9%		**Calculated Rate of Return on Equity - Real**	9%	
Debt Fraction	50%		**Debt Fraction**	50%	
Tax Rate (Federal and State)	40%		**Tax Rate (Federal and State)**	40%	
After Tax WACC - Real	5%		**After Tax WACC - Real**	5%	
Depreciation Period	5		**Depreciation Period**	5	

Modeling Procurement Auction Prices

We forecasted procurement auction prices (varying with the expected price of natural gas) based on historical Pennsylvania procurement auction prices in the past three years. We used a dispatch curve spreadsheet depicting the PJM region to predict how these auction prices would change in the future as electricity demand changes, generating units are added and retired, new renewables are added to meet PJM state requirements, and natural gas prices vary over time. Our dispatch analysis includes an adder to account for the capacity, auxiliary services and AEC prices that are included in auction prices (as discussed below).

Dispatch curve spreadsheet

We designed a spreadsheet depicting the “dispatch curve” for the PJM region using data from

U.S. Energy Information Administration (EIA) Forms 860 and 923. A dispatch curve presents available electric generating resources by the size of the resource in megawatts (MW). These resources are ordered by their total variable costs based on EIA fuel price projections and average non-fuel variable operations and maintenance costs. Each resource or group of resources is a column in the dispatch curve such that its height represents its total variable cost per kWh and its width represents its available MW. When compared to PJM load in a given hour, the dispatch curve makes it possible to estimate the variable cost of the marginal resource in that hour.

Using the dispatch curve, we estimated marginal prices for the PJM region for ten groups of hours in a year, each of equal size, organized by the scale of electricity demand. The average of these ten marginal price estimates is our estimated average wholesale price for a given year. We perform this analysis twice: once with a focus on hours of the year in which wind resources are running, and a second time with a focus on the hours of the year in which solar resources are running. This analysis is conducted for each year from 2015 to 2030. Projected electric sales and peak load, and the distribution of sales across the hours of the year are based on PJM data.

Natural gas price assumption

We ran our dispatch analysis three times with three different natural gas price forecasts using data from EIA's Annual Energy Outlook for 2017 for:

- **Low:** High oil and gas resource and technology case
- **Base:** Reference case
- **High:** Low oil and gas resource and technology case

Wholesale price adder

Per Pennsylvania's bidding rules for default service procurement auctions, a portion of the prices paid to winning suppliers in the fixed-price auction consists of the real time hourly locational marginal price plus an adder of $20/MWh, which "is designed to capture an estimate of costs of other supply components associated with meeting the full-requirements obligation, including capacity, ancillary services, NITS, AEPS compliance, and other costs."[26] Pennsylvania has already created more Tier I and II credits than it needs for compliance in 2021 and is assumed to be able to comply with its AEPS requirement for those technologies in that year; however, solar credits in 2015 were over 200,000 less than what will be needed in 2021.[27] Analysis of existing and proposed resources by the state indicates that sufficient Tier I and II resources are or will be

[26] CRA International. Bidding Rules For Fixed-Price and Hourly-Priced Auctions to Procure Default Service Products Under Default Service Program DSP-IV for Metropolitan Edison Company ("Met-ed"), Pennsylvania Electric Company (Penelec"), Pennsylvania Power Company ("Penn Power"), and West Penn Power Company ("West Penn").

[27] PA Public Utility Commission. 2015 Annual Report: Alternative Energy Portfolio Standards Act of 2004. Page 11.

available to meet the 2021 requirement, but solar obligations will only be met through 2019.[28]

A greater supply of Tier I and II resources has resulted in lower AEC prices, with the weighted average price in the 2015/2016 reporting year at $14.56 for Tier I and $0.10 for Tier II, respectively.[29] Solar capacity is in shorter supply, as reflected in weighted average price for Solar AECs in the 2015/2016 reporting year at $62.06.[30] Pennsylvania is expected to need approximately 645 MW of solar capacity to meet the 2021 generation requirement, which is an increase of 422 MW above 2015 in-state capacity.[31] The state is expected to need some percentage of out-of-state AECs to meet its solar requirement.

Because solar AECs are priced at a premium relative to Tier I and II renewables, we added additional $5/MWh to the model's total calculated procurement auction price (on top of the LMP plus $20/MWh) to account for the increased cost associated with solar energy.

[28] Id. Page ii.

[29] PA Public Utility Commission. 2016. Alternative Energy Credit Pricing. Page 1.

[30] Id.

[31] PA Public Utility Commission. 2015 Annual Report: Alternative Energy Portfolio Standards Act of 2004. Page 27.

VI. Appendix B: MAREC Member Survey

All responses were collected anonymously.

Please describe the most useful example PPA for the Pennsylvania renewable long-term contract modeling project:

1. Type of installation (technology)
2. Size of installation (kW)
3. Lifetime of installation (years)
4. Length of the PPA (years)
5. Overnight cost per kW ($)
6. Are there any soft costs not incorporated into the $per kW?
7. Flat or escalating PPA price (if escalating, at what rate)
8. Expected capacity factor (%)
9. Expected distribution of generation by month
10. Weighted average cost of capital
    a. Debt (assumed rate and % contribution)
    b. Equity (assumed rate and % contribution)
    c. Other (assumed rate and % contribution)
11. Your expectations regarding renewal of PTC and ITC
12. How do PTC/ITC incentives factor into your financial projections (i.e. does every penny of incentive flow through into the PPA or is only a portion of it available because the tax credit is being sold)?
13. If a request for renewable PPAs were issued in the next year:
    a. Would it be reasonable to assume that the construction start date (as defined by IRS rules) for most projects predates 2017?
    b. If not, what would be a reasonable construction start date to assume?
14. Other details that you would like to suggest for example PPAs