Pennsylvania's Solar Future Plan

Public Review Draft

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ACKNOWLEDGEMENTS

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Office of the Consumer Advocate	PA Public Utility Commission	PJM Interconnection
PennFuture	The Reinvestment Fund—Sustainable Development Fund	SEDA-COG
Tesla/Solar City	The Nature Conservancy	The Sustainable Energy Fund of South Central Pennsylvania

Stakeholders: This project wouldn't be possible without the efforts of the over 500 stakeholders that have participated over the past year. This included attending quarterly meetings and additional webinars, as well as efforts reviewing and commenting on several draft documents. Names of these stakeholders appear in Appendix A.

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ABBREVIATIONS AND ACRONYMS

AEPS – Alternative Energy Portfolio Standard	MWh – Megawatt hour
AEC – Alternative Energy Credit	NPV – Net Present Value
ATB – Annual Technology Baseline	NREL – National Renewable Energy Lab
CAFÉ – Corporate Average Fuel Economy	O&M – Operation and Maintenance Costs
CAGR – Compound Annual Growth Rate	PUC – Public Utility Commission
CFA – Commonwealth Finance Authority	PV – Photovoltaic
DEP- Pennsylvania Department of Environmental Protection	PACE – Property Assessed Clean Energy
DER – Distributed Energy Resources	PASF – Pennsylvania Solar Future
EDC- Electric Distribution Company	PEDA – Pennsylvania Energy Development Authority
EGS – Electric Generation Supplier	PEV – Pluggable Electric Vehicles
EIP – Energy Investment Partnership	PJM – PJM Interconnection LLC
EV – Electric Vehicle	PPA – Power Purchase Agreement
FERC- Federal Energy Regulatory Commission	PUC – Pennsylvania Public Utility Commission
GATS – Generation Attributes Trading System	REC – Renewable Energy Credit
GHG – Greenhouse Gas	RGGI – Regional Greenhouse Gas Initiative
GWh – Gigawatt hour	ROI – Return on Investment
IPP – Independent Power Producers	RPS – Renewable Portfolio Standard
ITC – Investment Tax Credit	RTO – Regional Transmission Organization
JEDI – Jobs and Economic Development Impact	SAM – System Advisor Model
kWh – Kilowatt hour	SACP – Solar Alternative Compliance Payment
LEAP – Long range Energy Alternatives Planning	SREC – Solar Renewable Energy Credit
LBNL – Lawrence Berkeley National Laboratory	TMI – Three Mile Island
LCOE – Levelized Cost of Energy	TOU – Time of Use
LTCs – Long Term Contracts	TWh – Terawatt hour
MACRS – Modified Accelerated Cost Recovery System	VOS – Value of Solar

EXECUTIVE SUMMARY

Today Pennsylvania is well situated to lead the country into the next age of energy development: clean, renewable solar photovoltaic (PV) energy. While nearby states have embraced solar development to a greater degree than Pennsylvania, the experience they gained can now be used here to enhance both distributed generation and large "grid scale" solar PV farms connected to the transmission grid. In fact, whereas in 2000, Pennsylvania had less than one Megawatt (MW) of solar installed, today, there are over 300 MW installed in Pennsylvania.[1]

Pennsylvania is moving forward in the solar marketplace, but there is significant potential for solar to continue this growth and transform the electricity generation sector. The benefits of an increased share of solar in the electricity generation sector are enormous, including:

Public Health	Air and water pollution from fossil fuels can lead to breathing issues, neurological damage, heart attacks, cancer, premature death, and a host of other serious problems that could be reduced with more clean energy generation.
Economic Growth	The solar industry is creating economic growth across the country, with some states taking full advantage.
Job Opportunities	The amount of solar jobs in the U.S. have increased. Since 2010 solar job growth has grown by 168 percent, from just over 93,000 to more than 250,000 jobs in all 50 states in 2017.[2]
Decreased Greenhouse Gases	The electricity sector accounts for 29 percent of all U.S. GHG emissions,[3] and Pennsylvania has the nation's third highest energy-sector GHG emissions,[4] providing renewable energy generation in Pennsylvania an opportunity the reduce U.S. emissions.

The *Finding Pennsylvania's Solar Future* planning project brought together expert stakeholders from across sectors to explore whether Pennsylvania has sufficient technical and economic potential to *increase in-state solar generation to provide 10 percent of in-state electricity consumption by 2030.* Stakeholders explored likely pathways to achieving that target and identified, through modeling, associated economic, environmental, and health impacts.

[1] http://www.puc.state.pa.us/Electric/pdf/AEPS/AEPS_Ann_Rpt_2016.pdf
[2] https://www.thesolarfoundation.org/national.
[3] https://www.epa.gov/sites/production/files/2018-01/documents/2018_complete_report.pdf
[4] https://www.eia.gov/environment/emissions/state/analysis/pdf/table1.pdf

Before the Finding Pennsylvania's Solar Future stakeholder process began, it was clear that Pennsylvania already possessed a unique set of assets that can position the state to take the lead in solar development and maintain its stance as an energy leader:

Resource potential	The Commonwealth's Energy Assessment Report states that Pennsylvania has the potential to economically increase grid scale solar 3,687 percent and distributed generation solar 255 percent from 2015 – 2050.[5]
Abundant land	Pennsylvania land is reasonably priced, available for grid scale solar development, and doesn't present the types of challenges faced by more mountainous or land constricted states may wrestle with.
Geographic location	Pennsylvania can benefit from the experiences of other East Coast states that have embraced solar development in a variety of ways, especially committing to a larger solar share than Pennsylvania.
Grid readiness	Pennsylvania's Regional Transmission Organization (RTO), PJM Interconnection LLC, studied the impacts to grid operations if renewable energy increases, finding that renewables integration can lower energy prices and concluded that the system can maintain required reliability levels with up to 30 percent of energy from wind and solar.[6]
Competitive prices	The Lawrence Berkeley National Laboratory *Tracking the Sun 10* report (2017) shows solar prices in Pennsylvania to be near the national average, especially in years (2010 – 2013) when more capacity was installed.
Interested project developers	In November 2017, the Commonwealth Financing Authority offered competitive grants for solar projects. In three months they received 110 applicants, approving 78 solar totaling 44 MW.
Market maturity	Solar is now a mature international and national market with competent and competitively driven developers, solar manufacturers, financiers, installers, utilities and others ready to work in Pennsylvania.

[5] Commonwealth Energy Assessment Report, 2018, Department of Environmental Protection

[6] PJM Interconnection, Renewable Integration Study, (March 2014) available at: http://www.pjm.com/committees-and-groups/subcommittees/irs/pris.aspx

With those assets in mind, stakeholders provided input regarding pivotal factors influencing solar PV deployment and associated considerations, risks, and benefits. Several stakeholder workshops were held across the state, with diverse sector participation (**FIGURE 1**). During each workshop, facilitators engaged stakeholders in breakout sessions for three main workgroups: Markets and Business Models, Policy and Ratemaking, and Operations and Systems Integration. Stakeholders provided feedback within these workgroups as well as during general listening sessions

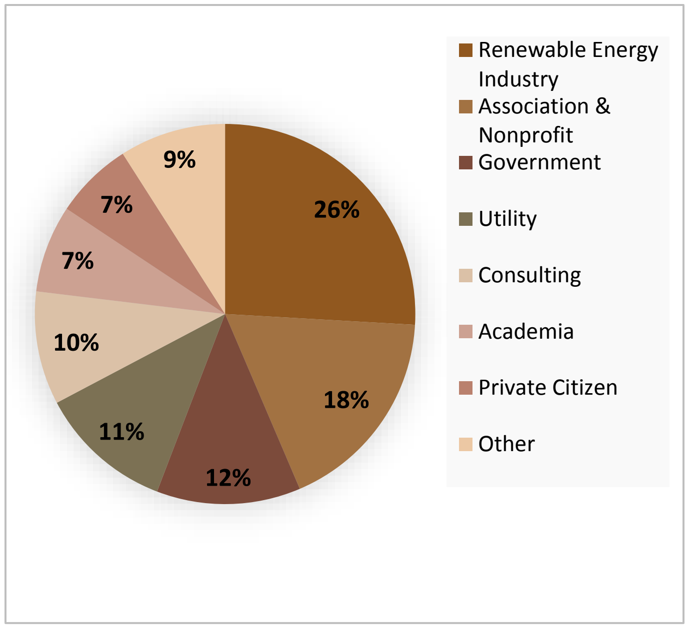

Figure 1. Percentage of Stakeholders by Sector

Table 1. Comparison of the basic assumptions of the three primary scenarios

	Reference	Solar A	Solar B
Target for in-state solar	0.5% by 2020	10% by 2030	10% by 2030
Total solar capacity in 2030	1.2 GW	11 GW	11 GW
Distributed capacity in 2030	0.6 GW	3.9 GW (35% of total) 50% residential 50% commercial	1.1 GW (10% of total) 50% residential 50% commercial
Grid scale capacity (>3MW) in 2030	0.6 GW	7.1 GW (65% of total)	9.9 GW (90% of total)

Stakeholder input was supported by a process of modeling and data analysis investigating three primary scenarios to achieve the 10 percent target by 2030: the **Reference Scenario,** the **Solar A Scenario**, and the **Solar B Scenario**.

The Reference Scenario assumes "business as usual" markets and energy consumption within the state and offers a baseline comparison. Solar A and Solar B Scenarios articulate two contrasting pathways for achieving 10 percent solar energy demand, using the same total energy consumption as in the Reference Scenario (**TABLE 1**) In the **Solar A** and **B** Scenarios, most of the new solar development comes from Grid Scale solar that is connected directly to the transmission and distribution system, rather than behind the customer meter.

The stakeholder engagement process worked to identify the most impactful and realistic strategies that would move Pennsylvania towards that the target of 10 percent solar by 2030. The stakeholders discovered that the pathway to successfully reaching the target will likely require a suite of strategies:

1) Cross-cutting (Grid scale and Distributed)
2) Grid Scale Solar Generation
3) Distributed Solar Generation

Their goal was to identify the most impactful effective strategies to maximize Pennsylvania's solar future.

CROSS-CUTTING STRATEGIES

The cross-cutting strategies, such as changes to the Pennsylvania Alternative Energy Portfolio Standard (AEPS) and adoption of carbon pricing, will dramatically impact both grid scale and distributed generation.

The key to the overall effort was to identify strategies that will bring the project costs of solar to a price point that will encourage the market's swift adoption of the technology. The price of solar is decreasing globally, and this is projected to continue, although perhaps at a slower pace than in the past decade. While the global supply and demand for solar modules are an important factor on price that the Pennsylvania market will have little influence on, there are several local factors that impact the installed cost for new solar in the state and policies and market conditions that impact the returns on solar investments. Implementing the cross-cutting strategies could shift the price point of solar and increase both grid scale and distributed generation.

Even if adopting these cross-cutting strategies influence the price point of solar, it is still necessary to consider costs and benefits associated with transforming the electricity generation sector. The modeling process helped guide stakeholder analysis by producing cost information relative to an increased level of solar development.

Cross-Cutting Strategies	
Alternative Energy Portfolio Standards	Implement an increase in the AEPS solar PV carve-out to between 4 and 8 percent by 2030 and ensure creditable SRECs are limited to those generated in Pennsylvania wherever possible.
Access to Capital	Increase access to capital by expanding availability of solar lending products to residential and commercial projects to enable solar ownership. Provide loan guarantees to lower interest rates and incentivize deployment of solar generation.
Carbon Pricing	Implement a carbon pricing program and invest the proceeds in renewable energy and energy efficiency measures.
Siting and Land Use	Support the creation and adoption of uniform policies to streamline siting and land-use issues while encouraging conservation. Provide support for brownfields development over land that can be used for other purposes.
Tax Incentives	Evaluate the state tax policy and consider exemptions that encourage the development of solar PV systems. Assist solar project sponsors in identifying investors and/or companies that have sufficient tax equity appetite to take full advantage of the federal ITC and Modified Accelerated Cost Recovery System (MACRS) depreciation if sponsors cannot do so themselves.

Economic cost: The modeling found that over 15 years, the Solar A and Solar B scenarios have average net annual economic costs ranging from $513 million to $613 million. These estimates represent the lifetime costs and savings associated with the solar capacity in each scenario compared to the reference scenario.

By way of context, Pennsylvania's annual energy expenditures are roughly $45 billion. Therefore, over the 15-year study period the investments required for the Solar A and Solar B Scenarios are just 1.2 to 1.4 percent above current energy spending.

Economic and environmental benefit: In addition, the modeling shows that the Solar A and Solar B scenarios both provide net economic benefits in excess of $25 billion from 2018 to 2030, when accounting for environmental externality costs. Further, in both scenarios, economy-wide greenhouse gas emissions decrease by 2-3 percent by 2030.

Land use: Another important issue identified by the stakeholders is how much land use would be required to achieve that level of solar development for both distributed generation and grid scale. The modeling found that grid scale solar would use 89 square miles (56,800 acres) in Solar A Scenario and

124 square miles (79,200 acres) in Solar B Scenario. Roof-top systems are not included in the land use numbers; however, a 2008 study on rooftop solar potential in Pennsylvania found that more there is space for more than 27 GW of solar PV panels on existing rooftops statewide alone, nearly three times the amount needed for the entire 10 percent target.

To put the acreage into perspective, the required land use to meet the grid scale levels for each scenario represent a negligible fraction (less than three-tenths of 1 percent) of Pennsylvania's total land area and less than half of the total abandoned mine lands in Pennsylvania. Therefore, it's clear there is more than sufficient available land to accommodate both scenarios of Grid Scale solar within Pennsylvania and land use strategies can be pursued.

Jobs. The modeling process estimated job impacts of the solar scenarios using the Jobs and Economic Development Impact (JEDI) model.[7] Combined with the itemized cost for solar installation and maintenance, the JEDI model uses economic input output analysis to provide an estimate of how much of the investment in solar recirculates within Pennsylvania, supporting local businesses and jobs. (**TABLE 2**).

Table 2. Estimated new gross jobs by scenario

	Solar A	Solar B
Construction period jobs	100,604	67,716
Ongoing jobs	1,086	983

GRID SCALE STRATEGIES

As the modeling scenarios discussed above indicate, any significant increase in statewide solar generation is expected to come, in large part, from grid scale deployments of solar. Although not necessarily required to meet the target, the modeling expects 65 to 90 percent of the solar generation to be grid scale.

While there are cross-cutting issues that reflect on all solar deployment, there are several approaches and considerations that are relevant to only grid scale that may help alleviate some of the hurdles currently holding back grid scale solar development in Pennsylvania.

[7] National Renewable Energy Laboratory, Jobs and Economic Development Model (JEDI), *available at:* https://www.nrel.gov/analysis/jedi/

Grid Scale Strategies	
Long-Term Contracts	Develop guidelines for limited use of long term contracts (LTCs) for a period of 10 or more years to ensure Pennsylvania benefits from grid scale solar energy. Evaluate and consider utility ownership of solar generation especially in cases where market-driven deployment may be insufficient to achieve public goals and/or reliability concerns. This may include solar for low income and Customer Assistance Programs in particular.
Grid Modernization	Investigate opportunities for grid modernization to enable increased solar generation.

Through the Pennsylvania Solar Future planning process, it became clear that grid scale solar will need to maintain a growth rate higher than it has averaged in the past to reach the target. However, other markets around the country have seen sustained growth well above the rates required by the solar scenarios.

In both solar scenarios, grid scale solar grows faster than distributed solar. This is because Pennsylvania, like other nascent solar markets, has significantly more distributed solar installed today than grid scale. The solar scenarios show quick growth in grid scale largely because that sector has driven the growth in most states with mature solar markets. Under either solar scenario, implementing the strategies above will require accelerated grid scale growth.

DISTRIBUTED GENERATION STRATEGIES

The modeling scenarios assume distributed solar generation will be responsible for a smaller fraction of the overall deployment than grid scale solar—likely between 10 percent and 35 percent. In order to meet these targets, the distributed generation annual growth rate would need to be sustained at current levels for the next 12 years. Current growth rates from 2013-2017 were 22 percent for residential and 7 percent for commercial solar. The following strategies could help to support and continue the growth seen in recent years and therefore meet the target for distributed generation.

Distributed Generation Strategies	
Virtual Net Metering	Expand customers' ability to use net metering.
Community Solar	Identify and remove the barriers to the deployment of community solar systems in Pennsylvania
Alternative Ratemaking	Ensure alternative ratemaking is addressed in a manner that does not create a disincentive for solar deployment
Property Assessed Clean Energy (PACE)	Enable and encourage municipalities to offer PACE programs that include solar projects.
Addressing Interconnection Issues	Accelerate use of smart inverters to manage over-voltage concerns on low voltage distribution lines and avoid unnecessarily adding costs on small solar distributed generation projects.

While the scenarios are dominated by a significant build out of grid scale solar in a manner not yet experienced in Pennsylvania, efforts should also be made to overcome barriers for distributed generation and community solar so Pennsylvanians may maximize the opportunities to develop all solar resources commensurate with broader social, environmental, and economic benefits.

The strategies contained in the PA Solar Future Plan recognize that with the removal of barriers for all sectors of solar development, the actual achievable solar penetration could far exceed the target of 10 percent by 2030 as is being demonstrated in many states in the region.

NEXT STEPS

The *Finding Pennsylvania's Solar Future Plan* demonstrates that by implementing strategies that increase solar generation, Pennsylvania will gain significant economic, environmental, and health benefits. Pennsylvania can continue its energy leadership role and advance policies that advance solar energy's role in the state. We recognize that achieving the 10 percent target by 2030 would be challenging and would take a sustained growth rate in excess of business-as-usual. But this plan challenges the narrative that solar can't work in Pennsylvania and presents several strategies that can be combined to create many pathways that lead to the 10 percent target, should policy makers commit to that path.

Going forward, the Pennsylvania's Solar Future Project Team and stakeholders will continue to discuss these strategies with an eye to implementation details and the keys to achieving market transformation, while minimizing ratepayer cost impacts.

Finding Pennsylvania's Solar Future is a project of the Pennsylvania Department of Environmental Protection (DEP) Energy Program's Office (EPO) with funding from the U.S. Department of Energy Solar Energy Technologies Office. DEP brought together a project team that, along with DEP and the U.S. Department of Energy, included Citizens for Pennsylvania's Future (PennFuture), The Vermont Energy Investment Corporation (VEIC) and Pennsylvania-based solar subject matter experts ("Facilitators") Sharon Pillar, Dr. Jeffrey Brownson, Ron Celentano, and Maureen Mulligan. The Project team took significant input from both our committed partners and our robust stakeholder group composed of over 500 members.

I. INTRODUCTION

Solar energy is growing as a clean and reliable electricity generation source across the world, including the United States. The U.S. has seen an average annual growth rate of installed capacity of 59 percent over the last ten years[8], and a 43 percent increase of solar electricity generation from 2016 to 2017[9]. Since 2000, solar in Pennsylvania has grown from less than one megawatt (MW) to over 300 MW today[10]. There is significant potential for solar to continue this growth and transform the electricity generation sector. In the U.S., the price of solar power has decreased 66 percent from 2010 and dropped 12 percent over the 2016 year alone.[11,12] Internationally, photovoltaic (PV) solar is expected to garner nearly $4 trillion in funding over the next 25 years. [13]

The potential benefits of an increased share of solar in the electricity generation sector are enormous, including:

- **Public health**: Air and water pollution from fossil fuels can lead to breathing issues, neurological damage, heart attacks, cancer, premature death, and a host of other serious problems that could be reduced with more clean energy generation. For coal alone, one study estimated the life cycle costs and public health effects to be an estimated $74.6 billion every year.[14]
- **Economic growth:** The solar industry is creating economic growth across the country, with some states taking full advantage. For example, North Carolina is home to over 450 companies involved in the solar industry that represent at least $2 billion of direct investment in the state.[15]
- **Job opportunities:** The amount of solar jobs in the U.S. have increased. Since 2010 solar job growth has grown by 168 percent, from just over 93,000 to more than 250,000 jobs in all 50 states in 2017.[16] Looking forward, one study suggests that there could be 7.2 million jobs in the U.S. solar industry by 2030.[17]
- **Stable energy prices:** Unlike other energy sources, solar (and wind) have no fuel costs and can provide fixed energy prices over time.
- **Decreased greenhouse gas (GHG) emissions:** The electricity sector accounts for 29 percent of all U.S. GHG emissions[18], providing renewable energy generation an opportunity the reduce U.S.

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[8] https://www.seia.org/solar-industry-research-data

[9] *See:* https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_1_17_b

[10] http://www.puc.state.pa.us/Electric/pdf/AEPS/AEPS_Ann_Rpt_2016.pdf

[11] SEIA, National Solar Database, www.seia.org/research-resources/national-solar-database. *Accessed* Dec. 30, 2016.

[12] Solar Foundation, 2015 National and State Solar Jobs Census, www.thesolarfoundation.org/solar-jobs-census/ Accessed Dec. 30, 2016.

[13] Bloomberg New Energy Finance, 2015.

[14] Epstein, P.R.,J. J. Buonocore, K. Eckerle, M. Hendryx, B. M. Stout III, R. Heinberg, R. W. Clapp, B. May, N. L. Reinhart, M. M. Ahern, S. K. Doshi, and L. Glustrom. 2011. Full cost accounting for the life cycle of coal in “Ecological Economics Reviews.” Ann. N.Y. Acad. Sci. 1219: 73–98.

[15] https://www.seia.org/sites/default/files/resources/Duke_CGGC_NCSolarEnergyReport.pdf

[16] https://www.thesolarfoundation.org/national.

[17] http://www.irena.org/documentdownloads/publications/irena_measuring-the-economics_2016.pdf

[18] https://www.epa.gov/sites/production/files/2018-01/documents/2018_complete_report.pdf

emissions. In fact, a study by the US Department of Energy's National Renewable Energy Laboratory (NREL) found that if the U.S. generates 80 percent of the country's electricity from renewable sources by 2050, the electricity sector's emissions could be reduced by approximately 81 percent.[19]

Pennsylvania, however, is not capturing all these benefits despite its role as an energy generation powerhouse. Pennsylvania is one of the top three energy production states in the nation, as well as the top electricity exporting state in the nation.[20] This energy leadership does not extend to renewable energy sources, as Pennsylvania ranks 21st in the nation when accounting for distributed generation solar and 28th in the nation for grid scale solar.[21] Installed solar energy generation assets currently produce less than 0.25 percent of the state's net electricity generation.

To maintain its energy generation leadership position, and to continue economic growth from the energy sector, Pennsylvania could include in its portfolio a greater percentage of renewable energy sources such as solar. There are several reasons Pennsylvania has the potential to take the lead in renewable energy and maintain its stance as an energy leader:

[19] https://www.nrel.gov/docs/fy13osti/52409-ES.pdf

[20] http://www.eia.gov/state/seds/sep_sum/html/pdf/sum_btu_totcb.pdf

[21] *See: https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_02_b*

Resource Potential	The Commonwealth's Energy Assessment Report states that Pennsylvania has the potential to economically increase grid scale solar 3,687% and distributed generation solar 255% from 2015 – 2050.
Abundant Land	Pennsylvania land is reasonably priced, available for grid scale solar development, and doesn't present the types of challenges more mountainous or land constricted states may wrestle with.
Geographic Location	East coast states have largely embraced solar development in a variety of ways, especially committing to a larger solar share than Pennsylvania, gaining experience that can be applied to Pennsylvania due to its proximity to those states.
Grid Readiness	Pennsylvania's Regional Transition Operator, PJM Interconnection LLC (PJM), commissioned a study to examine the impacts to grid operations, including energy prices, if renewable energy increases over the next 15 years. The final report found that renewables integration can lower energy prices and concluded that the PJM system can maintain required reliability levels with up to 30 percent of energy from wind and solar if transmission systems are expanded to meet changing power flows.[22]
Competitive Prices	The Lawrence Berkeley National Laboratory (LBNL) *Tracking the Sun 10* report (2017) shows solar prices in Pennsylvania to be near the national average, especially in years (2010 – 2013) when more capacity was installed.
Interested Project Developers	In November 2017, the Commonwealth Financing Authority offered competitive grants for solar projects. In three months they received 110 applicants, approving 78 solar totaling 44 MW.
Market Maturity	Solar is now a mature international and national market with competent and competitively driven developers, solar manufacturers, financiers, installers, utilities and others ready to work in Pennsylvania.
Adequate Rooftop Space	A 2008 study on rooftop solar potential in Pennsylvania found that there is space for more than 27 GW_{DC} of solar PV panels on existing rooftops alone.[23]
Community Support	In March 2018 a bipartisan group of 180 mayors from across the U.S. called for increased solar energy usage in a letter released by Environment America. The letter highlighted the commitment from cities and towns to support solar, as well as a call for more action to advance solar from the Federal government. There were 42 mayors from Pennsylvania who signed, the most from any one state.

[22] *See:* http://www.pjm.com/-/media/committees-groups/subcommittees/irs/postings/pris-executive-summary.ashx?la=en

[23] This assumes 18% of single family homes, 65% of multifamily homes and 65% of commercial buildings have roofs with adequate solar access. ACEEE Pennsylvania Solar Assessment, VEIC, Nov 25th, 2008.

These conditions highlight the important need to investigate the pathways to advance solar deployment in Pennsylvania. The *Finding Pennsylvania's Solar Future* project set a target for Pennsylvania to reach 10 percent of electricity consumption to come from in-state solar generation resources by 2030. However, there are existing barriers and challenges that need to be addressed before the potential of solar in Pennsylvania can be fully realized. This project was designed to help identify strategies to overcome those challenges, quantify costs and benefits, and document how opportunities to increase solar, if implemented, will benefit Pennsylvania.

A. ORGANIZATION OF THE REPORT

This report is presented in seven main sections.

Project Overview: Background information about the project, including the project team, the ten percent target, and project approach are described in this section.

Stakeholder Engagement: The stakeholder engagement section highlights how over 500 stakeholders and committed partners helped participate in this project through meetings, podcasts, webinars, and more. The list of stakeholders who participated in this project can be found in Appendix A.

Pennsylvania's Energy System: A summary of energy generation and usage in Pennsylvania that provides relevant context for the modeling and strategies described later in the document.

Solar Energy in Pennsylvania: A specific discussion of solar energy in Pennsylvania including the history of solar in the Commonwealth, current economic outlook for solar, and any important legislation impacting potential solar growth.

Modeling Pennsylvania's Solar Future: A detailed description of the modeling scenarios, assumptions, inputs, and process that supports this plan.

Modeling Results: The results of the modeling including technical potential of solar, growth required to reach the target, investment requirements, job creation, and potential emission reductions. Additional data on the modeling scenarios provided in Appendix B.

Pennsylvania's Solar Future Strategies: A discussion of the key strategies that may support achieving a high level of solar development in Pennsylvania. This section categorizes those strategies as cross-cutting measures that effect both grid scale solar and distributed generation, as well as strategies targeted and grid scale or distributed generation separately.

II. THE FINDING PENNSYLVANIA'S SOLAR FUTURE PROJECT

The Finding Pennsylvania's Solar Future project was led by the Pennsylvania Department of Environmental Protection (DEP) Office of Pollution Prevention and Energy Assistance (OPPEA). The project was funded by a grant from the U.S. Department of Energy Solar Energy Technologies Office, who also provided guidance and feedback throughout the project. DEP's objective in the Finding Pennsylvania's Solar Future project was to create a forward-looking solar energy plan for Pennsylvania as a product of broad stakeholder engagement that was informed by, and represents, key policy, regulatory, and market issues from many relevant perspectives.

The Pennsylvania's Solar Future Project Team ("Project Team") consisted of representatives from DEP, Citizens for Pennsylvania's Future, The Vermont Energy Investment Corporation and Pennsylvania based solar subject matter experts ("facilitators") Sharon Pillar, Dr. Jeffrey Brownson, Ron Celentano, and Maureen Mulligan. The Project Team additionally was informed and supported by both committed partners and a robust stakeholder group.

A. PROJECT TEAM

Citizens for Pennsylvania's Future (PennFuture) acted as the lead contractor and provided project management services and overall supervision of the project.

Vermont Energy Investment Corporation (VEIC) was responsible for the modeling tasks in the study. The general output for the modeling portion of the Pennsylvania Solar Future Project was to provide documented analysis-based support and findings on the feasibility and implications of meeting the Plan's goals. Their work has drawn upon the experience and approach for modeling the potential for Vermont to become an advanced solar economy.[24]

Project Facilitators had experience in specific areas and guided the stakeholder discussions, served as expert resources, conducted gap analysis, developed stakeholder diversity and cohesion, and captured the discussion in report writing and presentations. Further, in post-meeting assessments, the Project Team debriefed to assess progress, incorporate ideas from the stakeholders, seek agreement on common terminology and develop a common understanding of key topical areas.

- **Sharon Pillar** is owner of the Hot Earth Collaborative LLC, a clean energy consultancy, working with clients such Environmental Entrepreneurs (E2) to raise business voices in support of clean energy policies. Sharon is the president of the Solar Unified Network of Western Pennsylvania (SUNWPA). She recently directed the 2.5 year Solarize Allegheny campaign helping residents and businesses to go solar, and during her eight years at PennFuture, she served as the project manager for solar programs.
- **Dr. Jeffrey Brownson** is an Associate Professor of Energy & Mineral Engineering at Penn State. Since 2007, the Brownson Group has advanced research in solar engineering, economics,

[24] For reports and information on the Vermont Solar Market Pathways project see www.vermontsolarpathways.org.

resource assessment, power simulations, and community solar. Dr. Brownson has taught nearly 1,000 graduates building pathways to solar careers and has served as faculty lead in the Solar Decathlon 2009. Penn State is an internationally recognized leader in solar energy research and education and serves as a Land Grant Institution.

- **Ron Celentano** is a solar energy industry consultant with Celentano Energy Services (CES), and President of Pennsylvania Solar Energy Industries Assoc. (PASEIA). Ron started working in the solar energy field over 40 years ago, with the last 20 years focused on solar PV. Ron's experience covers both technical and policy related fields, and he has helped shape Pennsylvania's laws and regulations regarding solar energy over the last 20 years, including net metering, interconnection, PA's solar share requirement, and many other related issues.
- **Maureen Mulligan** is a government relations strategist and lobbyist for PASEIA/MSEIA and PV Now (currently SEIA) where she led efforts resulting in the successful passage of key solar bills. She is the owner of Sustainable Futures Communications, LLC and previously worked on Public Utility Commission (PUC) solar and renewable energy rulemakings, nominations, and virtually every major and minor solar issue that came before the Pennsylvania General Assembly. Maureen has participated as a solar and energy efficiency advocate, speaker and spokesperson on a regular basis and received several awards for her work in this area.

Committed partners from organizations across the state provided consistent support throughout the project by attending meetings, reviewing documents, contributing in-kind support, and offering perspectives from their organizations on how Pennsylvania can increase solar deployment.

Over 500 stakeholders representing the solar industry, utilities, academia, government, the public interest sector, and consumers participated in meetings and webinars, and reviewed draft documents. The stakeholders were an essential part of developing valuable insights and consensus on complicated market, policy, and technical issues in the Pennsylvania solar sector. The complete list of stakeholders is provided in Appendix A.

B. PROJECT GOALS

The Project Team, committed partners, and stakeholders came together to explore the pathways to increase solar energy production in Pennsylvania such that a target of 10 percent of Pennsylvania's electricity consumption may come from in-state solar generation resources by 2030. Reaching that target would represent an approximate additional deployment of over 11 GW of solar generation capacity in Pennsylvania over the next 12 years. The Project Team undertook a stakeholder engagement process that included sustained interaction with hundreds of stakeholders across the state to address:

- **Adapting current regulatory requirements** such as Pennsylvania Alternative Energy Portfolio Standard, including its provisions for net metering, to support forward looking economic and environmental objectives, and the role of utilities in owning solar generation;
- How market incentives, conditions, and rules should **ensure benefits of solar for low and moderate-income** consumers, manufactured home communities, and other traditionally under-represented parties.

- What soft-cost and market-enabling strategies could **help promote dissemination of cost-effective solar** in Pennsylvania; and
- What modifications in planning, operations, and system integration—including utility and solar industry interconnection and system operations expertise, the use of storage, load shifting, advanced metering infrastructure and other distributed energy resources—could **enable cost effective integration of solar into the overall resource portfolio.**

The Project Team and stakeholder group deployed an iterative process to develop and analyze technical and policy elements of pathways to significantly increase in-state solar deployment in Pennsylvania. The target of 10 percent solar by 2030 was set by Pennsylvania DEP as a level that could be accepted as achievable by 2030 but would also challenge the business-as-usual model. The modeling process allowed the stakeholders to explore technical issues related to significantly more solar deployment occurring in Pennsylvania in the coming years and discuss how market forces influence the adoption of solar generation.

While the Project Team and stakeholders investigated the influence of various laws, regulations, and other regulatory policies and provisions at the federal, state, and local levels that may impact reaching the 10 percent project target, this plan does not focus on advocacy for one solar deployment pathway, but instead presents stakeholder-based reviews of available paths to achieving the target.

The PA Solar Future Project Team believes that implementation of the strategies provided in this plan will continue to require collaborative planning involving a variety of experts, advocates, and citizens, working for a cleaner energy sector in Pennsylvania. The hope is that this PA Solar Future Plan will offer a model for states with similar energy generation profiles looking to increase the deployment of solar resources.

C. ESTABLISHING THE 10 PERCENT TARGET

To develop approaches to increased solar deployment, it was necessary to set a planning target that was significant enough to require actions beyond the business-as-usual approach while still being achievable. The Project Team used detailed, scenario modeling to compare current solar development and legislation / regulation to alternative levels of solar development culminating in 10 percent of electricity sales (10 – 12 GW) from in-state solar generation by 2030. While this 10 percent target is significantly higher than Pennsylvania's current AEPS requirement of 0.5 percent in 2021, Pennsylvania's current target is significantly lower than several neighboring PJM states (**TABLE** 1).

Table 1. Peak solar share by state RPS program

State	Year	Peak Solar Share
District of Columbia	2032	5%
New Jersey[25]	2021	5.1%
Delaware	2025	3.5%
Maryland	2020	2.5%
Illinois	2025	1.5%
Pennsylvania	2020	0.5%
Ohio	2027	0.5%
North Carolina	2022	0.2%

It is important to distinguish the purposes of the Finding Pennsylvania's Solar Future project target and the current Pennsylvania AEPS solar requirement or target. The AEPS requirement is an enforceable obligation mandated by law and regulation. The Solar Future project target is for planning purposes only. The project target is intended to inform methods that will identify the benefits of a higher penetration of solar, contribute to Pennsylvania's compliance with current solar targets, and provide increased fuel diversity. This effort will result in a plan for solar deployment that will be available to policy makers, regulators, industry, investors, and consumers. This well-informed planning effort is expected to help lower the costs, time, and barriers to the market expansion of solar.

It is important to note that, during the stakeholder process, the project stakeholders did not reach a consensus whether the 10 percent solar target by 2030 was too low, too high, or in the correct range. However, the project moved forward with the understanding that, should a goal of 10 percent solar by 2030 be adopted, the identified strategies represent a pathway to accelerate solar deployment in Pennsylvania to that level. In response to stakeholder input, the Project Team conducted sensitivity analyses showing a range of solar targets from 8 to 12 percent.

D. APPROACH

The purpose of the Finding Pennsylvania's Solar Future project was to develop approaches to reduce the costs of solar as well as achieve deeper understanding of the barriers to solar deployment and associated policy solutions. The project aims to examine how solar technologies, the electric grid, technology providers, and installers in the solar marketplace can address challenges to achieving a greater penetration of these resources while maximizing the benefits of solar as it pertains to economic development, emissions reductions, reducing fuel price volatility, grid stability and security, resource diversity, expanding access to electricity, grid resiliency and meeting the objectives of a rapidly changing energy economy.

Toward that end, this plan is less about "forecasting" Pennsylvania's solar deployment future, and more about constructing rigorously analyzed stakeholder-guided scenarios showing possible future strategies to a strong solar market in Pennsylvania. The plan seeks to provide economic and policy strategies, including identification of jobs and business opportunities for Pennsylvanians. These efforts will lead to a

[25] A.3734 (McKeon) passed in the legislature on April 12, 2018 (*pending approval of the Governor*) establishes a 5.1 percent peak share that declines after FY 2023.

deployment plan that illustrates options for exceeding Pennsylvania's current AEPS requirements and ultimately achieving a target of 10 percent of electricity sales from in-state solar systems by 2030.

The Project Team's approach was to operate the stakeholder input process as non-binding and non-authoritative, but to be clear in its attempt to inform future engagement and decisions. The integrative process practiced through workshops and webinars created a repeated series of engagement events across the commonwealth. The workshops employed a process of integrative design, whereby the stakeholders' vision and preferences are aligned over repeated engagement in service to the people and businesses of the Commonwealth of Pennsylvania while also holding to compliance with project objectives. The development process thus commenced by repeatedly aligning the stakeholders' shared identity and purpose, motivation for change, and development and integration of human capacity among the diverse participants.

Throughout the effort, the stakeholder process attempted to document and synthesize agreement and disagreement into coherent future solar development scenarios for the 5- and 10-year horizons. The approach also included detailed energy supply/demand balance scenario modeling to help facilitate the stakeholder discussions, findings and the development of the report.

In order to ensure stakeholders had adequate opportunities to discuss scenarios, strategies, and challenges, three different groups were created with each one managed by a Project Facilitator.

Markets and Business Models (MBM) Workgroup, chaired by Sharon Pillar: The MBM Workgroup was charged with identifying the pivotal factors that may impact the various solar markets either positively or negatively in Pennsylvania through 2030.

Solar markets were defined as residential, commercial (including businesses, non-profits, schools, hospitals, institutions, and government) or industrial. Markets reflect the customer base (*i.e.,* who is purchasing the solar energy) and the unique characteristics of those market segments including the size of the solar systems, financing considerations and return on investment, incentives, regulations and policies, siting and permitting issues, and workforce development. Business models refer to the structures that permit the various market sectors to acquire solar and include such topics as ownership models, and other associated factors that allow for the development of those business models.

The MBM Workgroup also discussed the need to include equity into the discussion so that systems and models could be structured to increase solar within populations with financial or physical challenges such as low-income, rural, non-profit organizations, buildings without good solar access, etc. The goal identified was that all people across Pennsylvania should have equal opportunity not only in realizing the economic and health benefits of solar energy, but also for accessing opportunities for education and employment in the emerging clean energy economy.

Operations and Systems Integration (OSI) Workgroup, chaired by Dr. Jeffrey Brownson: The OSI workgroup endeavored to explore and integrate the technical, legal, and organizational challenges associated with the grid in Pennsylvania and the growth of solar power production on the grid.

Systems integration involves managing suites of generators, power transmission and distribution, and diverse user demands. Systems operation is bound by physical limitations and legal constraints. Pennsylvania's Electricity Generation Customer Choice and Competition Act of 1996[26] resulted in the restructuring of electricity markets through opening generation to competitive supply with state regulation of transmission and distribution of power. From the engineering perspective, Pennsylvania is a very energy dense state, with a diverse portfolio of energy demand, energy exports and new power generation sources emerging.

Major topic areas which were discussed included factors that will enable both grid scale solar (often called utility-scale solar) as well as distributed generation solar (e.g. customer-sited, rooftop solar) growth within the commonwealth, with careers benefiting the surrounding communities as well. Additionally, Pennsylvania does not currently have significant contributions of grid scale solar power. The OSI Workgroup explored reasons as to why that is currently the case and how to increase grid scale solar power.

Regulatory and Ratemaking (RR) Workgroup, chaired by Ron Celentano: The RR Workgroup helped define the context under which market participants, including, but not limited to, the regulated utilities make investment and other business decisions.

Regulations establish the rules under which solar and other resources can participate and compete in the market. Regulations that impact solar and other energy generation systems are set at the local, state, regional and federal levels. For example, permitting or zoning often operates at the local municipal level where net metering is largely controlled by state-level policy. PJM's market structure and rules operate at the regional level, while Federal legislation or regulations impact environmental requirements, establish tax policy, and provide oversight of grid operators such as PJM.

Ratemaking is intended to identify the costs for providing services and fairly and adequately distribute those costs among rate classes. In practice, each customer carries the burden for costs based on an average of the customer class, rather than assigning to each individual customer the costs that are created and borne by that individual. In addition, the ratemaking process may consider issues and concerns about cross-subsidization issues among customer classes. The RR Workgroup was charged with identifying the legislative and regulatory issues that would either promote or detract from achieving a notable increase of solar penetration in Pennsylvania and then helping to shape strategies to maximize solar development.

[26] Act of Jul. 2, 1996, P.L. 542, No. 94. (See: 66 Pa. Stat. Cons. § 2801 et. Seq.).

III. STAKEHOLDER PARTICIPATION AND PUBLIC ENGAGEMENT

Stakeholder engagement was a critical part of the development process for Pennsylvania's Solar Future Plan. Input from a diverse pool of stakeholders informed and validated the reference scenario, provided input regarding pivotal factors influencing solar deployment, and provided insight into all topical areas and approaches to potential implementation. The stakeholders ultimately provided valuable feedback on every aspect of the process leading up to the development of this plan.

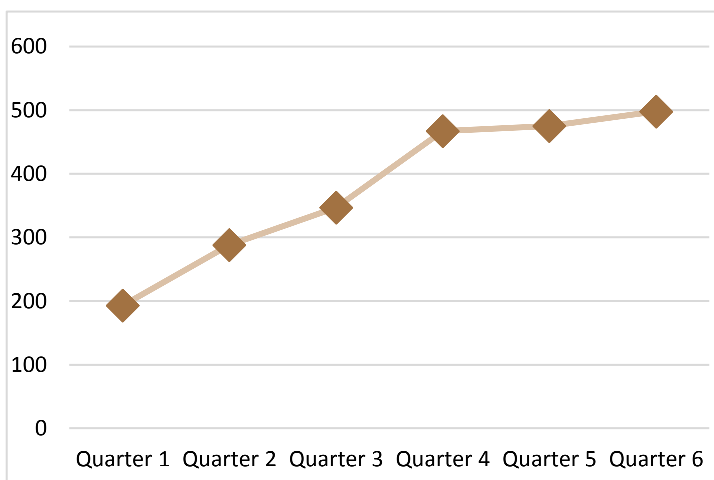
Stakeholder Participation

To engage with as many stakeholders as possible, the Project Team held quarterly one-day long stakeholder engagement meetings across the state rotating between Harrisburg, Pittsburgh, and Philadelphia during the first phase of the project. At least 100 stakeholders participated in each meeting either in-person or through a concurrent web-conference. At each meeting, the Project Team provided project updates and plans to the stakeholders, held discussions on various solar topics, as well as spent the afternoons providing stakeholders an opportunity for feedback, discussion, and ideas about how to increase solar deployment in Pennsylvania.

The Project Team also hosted four webinars in between stakeholder meetings that covered topics relevant to Pennsylvania's solar industry. The webinar topics included alternative ratemaking, low-income solar development, stakeholder meeting preparation, and the LEAP – Long Range Energy Alternatives planning modeling system. Webinars and stakeholder meetings included panels and discussions provided by experts from across the country. At the end of each discussion, whether it be during stakeholder meeting or webinars, there was an opportunity for questions and discussions from stakeholders.

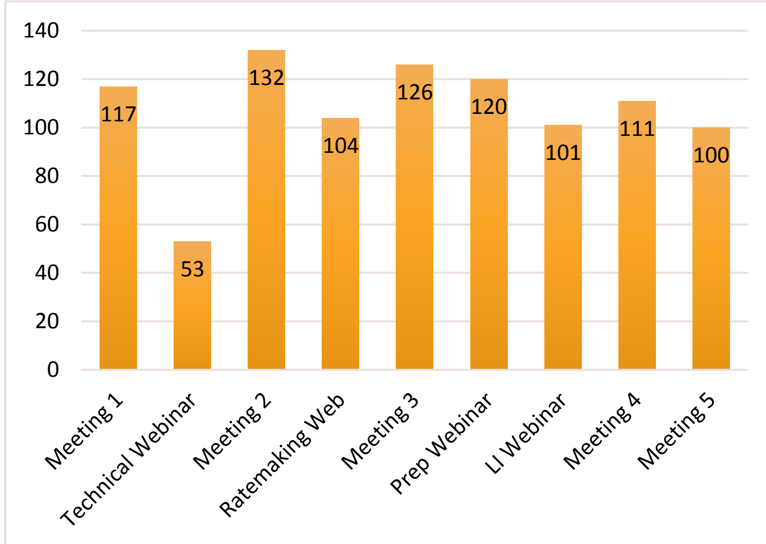
As the stakeholder process unfolded, the number of total stakeholders continued to increase (**FIGURE 1**) and most stayed engaged with the project (**FIGURE 2**). The stakeholder group

Figure 1. Number of Stakeholders by Quarter



stems from a diverse combination of backgrounds including renewable energy industry, government, utilities, nonprofits, academia, consulting, and others (**FIGURE 3**) that led to productive contributions from different perspectives. Continued and substantial engagement from stakeholders provided valuable feedback and validation on the reference scenarios and strategies that ultimately made up Pennsylvania's Solar Future Plan.

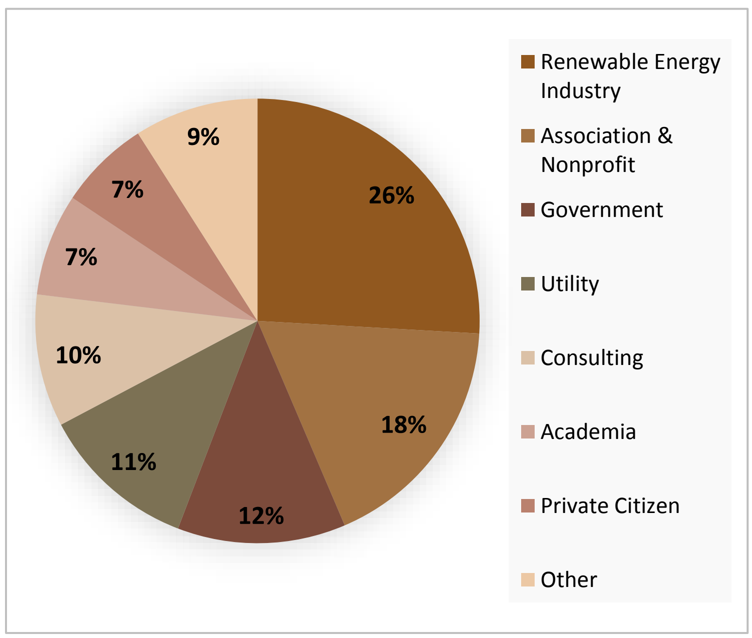
Figure 2. Number of Stakeholders Attending per Event



Public Engagement

There is a tremendous amount of interest about solar energy growth in Pennsylvania. As a result, the Project Team worked to engage with media and the public to highlight project progress and keep them informed of project outcomes.

Figure 3. Percentage of Stakeholders by Sector



Governor Wolf's press release announcing the start of the project led to several radio and newspaper stories. Included in this was an interview with Pennsylvania DEP Secretary Patrick McDonnell on WITF, the regional National Public Radio affiliate, that provided an overview of the project and expected outcomes.

DEP followed on with a series of social media posts and blogs on DEP's webpages and social media accounts including a video and blog post about how every Pennsylvanian can put solar on their home. DEP Secretary McDonnell also authored a blog post titled "The Sun Is Rising on Solar Energy in PA" that described the positive momentum solar is generating in Pennsylvania, and how to continue the momentum.

In addition, select committed partners participated in a podcast with Pennsylvania's Environmental Council's Josh Raulerson. Project participants Roger Clark, Director of Clean Energy at the Reinvestment Fund, Professor Vera Cole, chair of the online Energy and Sustainability Policy Program at Penn State, and Stacy Richards, founding director of the SEDA-COG Energy Resource Center, discussed what barriers exist to increasing solar energy production, how they can be removed, how Pennsylvanians can at all socioeconomic levels enjoy the benefits of solar, and other questions in the interview.

The Project Team believes that engaging the public in a variety of ways helped attract stakeholders, therefore receiving more input and ideas on how Pennsylvania can increase solar energy across the state.

IV. PENNSYLVANIA'S ENERGY SYSTEM

The stakeholder discussions informing the development of strategies and the analysis of technical and policy elements to significantly increase in-state solar deployment in Pennsylvania have taken place in the context of Pennsylvania's position in the PJM Region and as a restructured electric market. This section discusses the various existing conditions that affect, or potentially will affect, solar generation in Pennsylvania.

A. ENERGY GENERATION PROFILE

Pennsylvania is the largest exporter of electricity in the nation with approximately 30 percent of production being consumed out of state. As shown in **FIGURE 4**, the two largest sources of the electricity on our grid are nuclear energy and natural gas (nuclear at 42 percent, followed by natural gas 30 percent and coal 24 percent)[27]. Each of these fuel sources competes for a significant share of the electricity generation marketplace. Despite retirement of thousands of MW of aging coal-fired generation, Pennsylvania is the nation's 6th largest producer of electricity from coal.[28] In addition, and in large part because of increased development of Marcellus shale, Pennsylvania has become the nation's second largest producer of natural gas. This has led to gas generation supplying a significant amount of the energy that was formerly provided by coal.

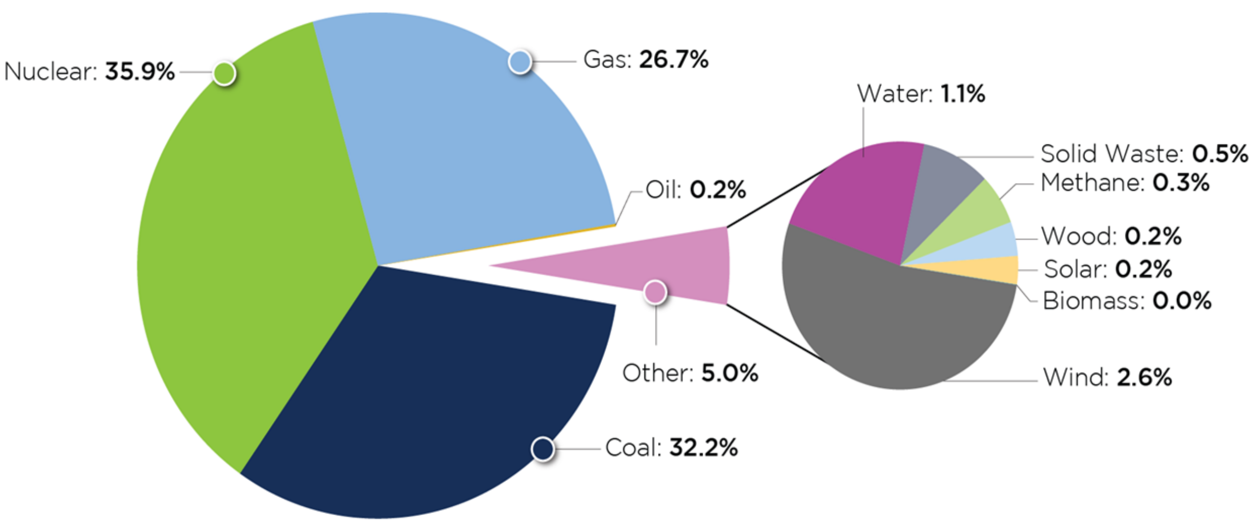


Figure 4. PJM 2017 fuel mix

Pennsylvania is also the second largest producer of electricity from nuclear power. There are currently five operating nuclear power stations in the state although the single 837 MW unit in operation at the Three Mile Island[29] Nuclear Generating Station (TMI) is anticipated to retire in 2019 after failing to clear

[27] See: EIA, Electric Power Monthly, Table 1.3.B and 1.17.B. Available at: https://www.eia.gov/electricity/monthly/current_month/epm.pdf
[28] Id.
[29] TMI Unit 2 has been closed since the accident in 1979.

the 2020 – 2021 PJM forward capacity auction. PJM has completed a reliability analysis related to the closure of TMI and expects facility could close without negative impacts to the grid.[30] On March 28, 2018, the owners of the 1811 MW Beaver Valley Nuclear Generating station notified PJM of their request to deactivate both of its units in 2021. PJM's analysis of this retirement similarly found that necessary upgrades are expected to be completed in time for the facility to deactivate as scheduled.[31] Legislative and policy measures that could impact the decisions to deactivate these units have been proposed but no specific measures have been approved.

Pennsylvania's status as a fuel rich state makes Pennsylvania a critical electricity supplier to the Mid-Atlantic region and the PJM Grid. In addition to traditional fuels, renewables currently provide only 4.1 percent of the electricity generation[32] ranking Pennsylvania 41st in renewable energy generation[33]. Solar photovoltaic (PV) installations are currently installed in Pennsylvania at residential, commercial, industrial and even grid scale but those assets currently produce less than 0.25 percent of the state's net electricity generation

B. ENERGY USAGE AND SHIFTS IN GENERATION SOURCES

While Pennsylvania's energy mix has been undergoing a significant change due to the impact of historic volumes of low cost natural gas entering the market, data from the US Energy Information Administration shows net utility-scale generation across all fuels has been relatively flat in Pennsylvania.[34] Negligible load growth is also reflected grid-wide with PJM's forward capacity auction[35] where no significant growth is expected for at least the next three years. The most significant changes in the fuel mix is gas replacing coal combined with a slower, but steady growth in renewable generation.

Excess natural gas supply leading to continued low gas prices is expected to have a significant influence in the electricity market, particularly in the near term. Pennsylvania experiences what has been termed the "Pennsylvania gas discount" where local gas hubs are seeing prices below that of the national average or key indicators such as the Henry Hub. This "discount" is typically attributed to increased supply of natural gas from Marcellus shale outstripping the capacity of pipelines to transport the gas to markets. This has had an impact on electricity generation with natural gas prices delivered to electric power plants in 2016, running $1.04/Mcf below the national average. While the electric utility sector is seeing these decreases, as are likely commercial and industrial buyers that contract individually for supply, residential citygate gas prices remain above the national averages.[36]

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30 PJM Interconnection, LLC., Future Deactivations (as of Oct. 27, 2017) (*available at:* http://www.pjm.com/-/media/planning/gen-retire/pending-deactivation-requests.ashx?la=en).
31 PJM, Generation Deactivations, (*available at:* http://www.pjm.com/planning/services-requests/gen-deactivations.aspx*)*
32 https://energy.gov/maps/renewable-energy-production-state
33 *Id.*
34 US Energy Information Administration, Electricity Data Browser (*available at:* https://www.eia.gov/electricity/data/browser/).
35 Source: PJM
36 C. Simeone, *Pennsylvania's Gas Decade*, Kleinman Center for Energy Policy (2017) (available at: http://kleinmanenergy.upenn.edu/sites/default/files/Pennsylvania%27s%20Gas%20Decade.pdf).

Regional Transmission and Market

Figure 5. PJM Territory

Pennsylvania's wholesale electricity market is managed by PJM Interconnection, LLC (PJM), the regional transmission organization (RTO) that serves approximately 61 million people in 13 states and DC across the mid-Atlantic, and Midwest as shown in (**FIGURE 5**[37]). Within this region, a significant amount of energy is sold at wholesale in a day-ahead market with a much smaller percentage being sold on the spot or "balancing" market. Within PJM, energy is also sold through bilateral agreements, including long term contracts, and via self-supply agreements involving rural electric cooperatives and municipal electric companies.

Pennsylvania's Restructured Electricity Market

For just over twenty years Pennsylvania has had a restructured electric market. Utility customers can shop for competitive generation suppliers or opt to have their regulated utility as their default supplier.[38] To the extent that utilities need to acquire energy to service their customers, they must do so using a PUC approved "prudent mix of contracts" that results in the "least cost over time" to consumers. Most industrial customers in Pennsylvania choose competitive generation suppliers whereas business and residential customers are far more likely to rely on their utility to serve as their default supplier.[39] Consumers benefitted from lower prices resulting from competitive forces and, for the first time, gained significant access to renewable energy largely through offerings from competitive electric generation suppliers (EGSs).

PA Powerswitch[40], a retail offering comparison tool supported by the PUC, provides residential consumers with the ability to find zip code-based listings of competitive offers. These can be filtered by fixed/variable rate, renewable content, cancellation charges and length of contract. For small and large

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[37] Source: Federal Energy Regulatory Commission (FERC).

[38] In addition to regulated utilities, 35 municipalities and 13 rural electric cooperatives provide power to customers but are not under Pennsylvania PUC jurisdiction and are not subject to any of the utility legislation discussed in this document.

[39] *See generally:* C. Simeone & J. Hanger, *A Case Study of Electric Competition Results in Pennsylvania*, Kleinman Center for Energy Policy (Oct. 2016) (*available at:* http://kleinmanenergy.upenn.edu/sites/default/files/A%20Case%20Study%20of%20Electric%20Competition%20Results%20in%20Pennsylvania_0.pdf).

[40] http://www.papowerswitch.com

businesses, a list of available suppliers is provided but the customer must contact them to secure pricing. There are dozens of suppliers providing hundreds of retail electricity offers including many based on renewable energy. In addition, the Pennsylvania Office of the Consumer Advocate also provides an Electric Shopping Guide with similar information.[41] Renewable energy includes solar resources located in Pennsylvania as well as wind generation located inside and outside of the state. Businesses also use this service, generally without charge, as a means for accessing competitive suppliers. As of October 2017, shopping varies from about a third of residential customers to about 75 percent of commercial customers to over 97 percent of industrial customers. In addition to competitive generation supply, Pennsylvania consumers can also enter into power purchase agreements (PPAs) that guarantee energy at an agreed upon price for a fixed term of years.

[41] *See:* http://www.oca.state.pa.us/Industry/Electric/elecomp/ElectricGuides.htm.

V. SOLAR ENERGY IN PENNSYLVANIA

As of December 31, 2017, Pennsylvania had a total of 318 MW of installed solar generation capacity from 16,770 solar systems spread across every county of the commonwealth. This approximately 0.3 GW of solar generation capacity in Pennsylvania is a small percentage of the additional 10 – 12 GW of capacity that would need to be deployed over the next 12 years to achieve the 10 percent goal of the project. Generation from these systems accounts for about 0.25 percent of the state's projected 2017 electricity consumption.

Table 2. Cumulative Photovoltaic Systems in Pennsylvania through 2017

Capacity (DC)	# of Systems	Total MW	% Total MW
< 15 kW	14,665	110	34.60%
> 15 kW to ≤ 1 MW	2,070	133	41.80%
> 1 MW to ≤ 3 MW	28	41	12.90%
> 3 MW to ≤ 5 MW	6	22	6.90%
> 5 MW to ≤ 10 MW	0	0	0.00%
> 10 MW	1	12	3.80%
Total	**16,770**	**318**	**100%**
		* as of 12/31/2017 as per PA AEPS (PUC)	

As shown in **TABLE** 2, more than 70 percent of the generation is produced by systems with a capacity of less than 1 MW, while only one system exceeded 10 MW.[42]

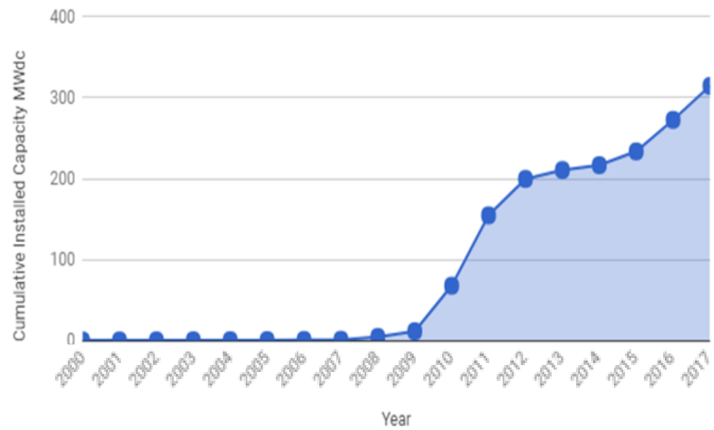
Terminology Note: This report uses *grid scale* to avoid possible confusion inherent in the term *utility scale*. Grid scale specifically refers to resources that participate in the PJM wholesale market or are larger than is typically interconnected to the distribution network. Their primary purpose is to produce electricity for sale and not to offset local demand. To the extent that the term utility scale is used it refers to these grid scale resources unless otherwise stated. In contrast, the term *distributed generation* is used for residential, commercial, or industrial sources of generation that are typically no larger than 3 – 5 MW and tied to the distribution network.

The marketplace in Pennsylvania has not followed a consistent trend over the last 10 years. Installation trends reflect additional incentives offered during the 2009 – 2012 time period, the loss of the incentive programs, and then significant lower costs for solar PV systems combined with the opportunities provided by residential solar leasing from 2016 onward. **FIGURE** 6 and **FIGURE** 7 show the cumulative and yearly installed capacity in Pennsylvania since 2000 based on PJM Generation Attribute Tracking System (GATS).

[42] AEPS data. We note there is a discrepancy between qualified systems report by the AEPS administrator and PJM GATS data.

Although Pennsylvania receives a very small portion of electricity from in-state solar generation, the use of solar for electric generation has the potential to be a significant resource in supplying reliable emissions-free electricity.

Figure 6. Cumulative Installed Solar Capacity



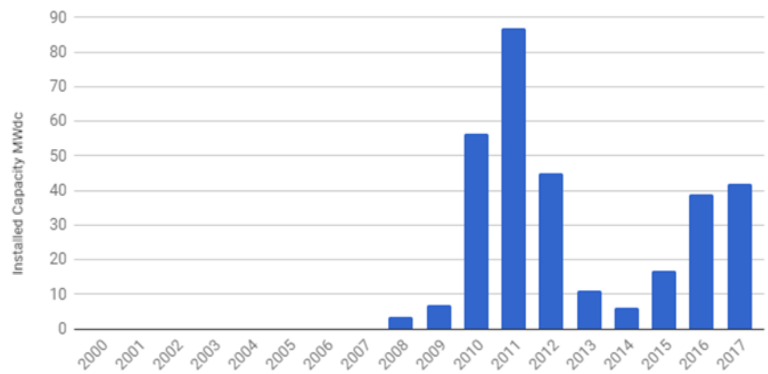


Figure 7. Installed solar capacity by year

Pennsylvania experiences 2,600 hours of sunshine annually. Pennsylvania solar installations are perhaps no different in opportunity for success than New Jersey, Massachusetts and New York. Each of these states is within the top 10 solar states in the nation (numbers 4, 6, and 8, respectively[43]) for solar photovoltaic electricity production. The sunshine that Pennsylvania gets is also evenly distributed across the state. In fact, projects that participated in DEP's Solar Sunshine Program spanned across each region of Pennsylvania and reported efficacy similar to one another, ranging from 1,143-1,026 kWh/kW/year (**TABLE** 3)." Furthermore, solar economics are based on solar output and the baseline cost of electricity being offset. The relatively high electricity prices in urban regions may make solar economic despite lower insolation than sunnier states.

	Average Reported Efficacy (kWh/kW/yr.)	
Region	**Residential**	**Commercial**
SE	1,108	1,091
SC	1,143	1,114
SW	1,061	1,026
NW	1,102	1,039
NC	1,088	1,030
NE	1,075	1,065

Table 3. Reported and Predicted Efficacy by Region of Pennsylvania

[43] See: https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_02_b

REDUCING THE COSTS OF SOLAR IN PENNSYLVANIA

The U.S. Department of Energy offers programs that include a number of initiatives aimed at reducing soft costs in the efforts to help solar PV reach cost parity with grid-supplied energy by the year 2020. One of these initiatives, the Solar Training and Education for Professionals (STEP) Program addresses roadblocks among secondary actors in the transactions that occur during a solar project.

The Building Codes Assistance Project is the lead project developer for one of the STEP programs, which is targeted toward design professionals such as architects and engineers. This training was developed throughout 2016, with enormous input from solar experts from across the country, and began offering full-day trainings early in 2017 with specially-trained trainers.

A. SOLAR JOBS IN PENNSYLVANIA

According to U.S. Department of Energy data, the solar workforce in 2017 increased to almost 374,000 employees working in the solar industry with more than 260,000 of those employees spending the majority of their time on solar.[44] Also, solar was found to comprise 43 percent of the electric power generation workforce, followed by fossil fuel generation employment. Fossil accounted for 22 percent of total electric power generation employment and supports 187,117 workers across coal, oil, and natural gas generation technologies.

Figure 8. Michael Skala of Exact Solar, Bucks County, PA

According to the U.S. Bureau of Labor Statistics, the occupation of solar installer is projected to be the fastest growing job in the United States from 2016 – 2026 and is expected to increase more than 100 percent through 2026.[45] By comparison, the average growth rate for all occupations is 7 percent. While the actual number of jobs in health care is projected to be greater, the solar job growth rate may achieve the highest increase by percentage of any other job.

Since 2010 solar job growth has grown by 168 percent, from just over 93,000 to more than 250,000 jobs in all 50 states in 2017.[46]

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[44] U.S. Dept. of Energy, *U.S. Employment and Energy Report,* 37 (Jan. 2017). *Available at:* https://www.energy.gov/sites/prod/files/2017/01/f34/2017%20US%20Energy%20and%20Jobs%20Report_0.pdf

[45] https://www.bls.gov/ooh/construction-and-extraction/solar-photovoltaic-installers.htm .

[46] https://www.thesolarfoundation.org/national.

According to the U.S. Department of Energy Employment & Energy Report, Pennsylvania had 4,670 people working at least some time in the solar sector in 2016.[47] The Solar Foundation Solar Jobs Census showed that Pennsylvania had 3,848 people working at least half time in the solar industry in 2017—a 26 percent increase from 2016—with 1 in every 1,523 jobs in Pennsylvania in the solar sector. However, Pennsylvania ranked 19th in the country in overall solar employment in 2017.

SOLAR JOBS POTENTIAL IN PENNSYLVANIA

The Solar Foundation released a report that included a comparison of MW of solar generated per capita between Maryland and Pennsylvania, finding: "Maryland saw 248 MW of solar installed in 2016. At more than 6 million in population, 2016 solar installations equate to 41 Watts per person. With approximately 12.7 million in population in Pennsylvania, a target of 41 Watts per person in 2021 would bring Pennsylvania to 524 megawatts installed that year." The report shows that a significant increase in solar capacity is possible if viewed in comparison to growth already being seen in Maryland.

Source: http://www.thesolarfoundation.org/wp-content/uploads/2017/06/TSF-Census-Future-State-Solar-Jobs-2021.pdf

TABLE 4 shows the states that surround Pennsylvania in the Northeast, the solar jobs to population ratio and the RPS goal, demonstrating that higher RPS goals can result in a greater number of jobs. Pennsylvania has the lowest goal and the lowest solar job ratio. Ohio's solar job to population ratio is likely higher due to requiring at least 50 percent of the solar accounted for to achieve the RPS goal originate from in-state projects, whereas Pennsylvania did not have an in-state project requirement until the end of 2017.

Table 4. Correlation of Number of Solar Jobs, Population and RPS Goal by Various State

State	Solar Jobs in 2017	2017 State Population (in millions)	Solar Job to Population Ratio	RPS Goal
Massachusetts	19,635	6.9	1:351	400 MW
Maryland	13,053	6.1	1:467	2.5% by 2020
New Jersey	9,239	9.0	1:974	5.1% solar-electric by 2021
Ohio	8,350	11.7	1:1401	0.5 by 2027
New York	12,411	19.9	1:1603	Not Applicable
Pennsylvania	4,670	12.8	1:2741	0.5% by 2021

[47] *Supra 11.*

1. JOB DIFFERENCES PER SECTOR

Distributed solar installations require larger numbers of workers to install one megawatt (MW) of capacity than projects for grid scale solar.[48]

illustrates the predicted number of solar "field" jobs (*i.e.* those workers who physically install systems) in the business-as-usual scenario versus modeled options that meet the 10 percent target with a relatively high fraction of distributed generation versus a relatively low fraction.

Table 5. Predicted solar job creation per sector by model scenario

	Jobs per MW	Reference Scenario		35% Distributed (Solar A)		10% Distributed (Solar B)	
Sector		MW Predicted by 2030	No. of Predicted Jobs	MW Predicted by 2030	No. of Predicted Jobs	MW Predicted by 2030	No. of Predicted Jobs
Residential Jobs	4.82	0.3 GW	1,446	1.95 GW	9,399	0.55 GW	2,651
Non-Residential Jobs	3.06	0.6 GW	1,836	1.95 GW	5,967	0.55 GW	1,683
Grid Scale Jobs	2.42	0.6 GW	1,452	7.1 GW	17,182	9.9 GW	23,958
TOTAL Number of Predicted Jobs by 2030		1.5 GW	4,734	11 GW	32,548	11 GW	28,292

The number of jobs per megawatt in **TABLE 5** above is based on national averages from the Solar Jobs Census.[49] The Pennsylvania residential solar sector may require more workers per megawatt than the national average, possibly due to older housing stock presenting additional challenges to installation.

2. WAGES

According to the Solar Foundation 2017 Annual Solar Job Census, "the median reported wage for mid-level installer positions for both installation and project development companies is $21 per hour. For installation companies alone, the median mid-level installer wage is $20, and for project development companies, the median wage is $25. The median wages for supervisory roles in the installation and

[48] *Supra* 13.

[49] *See: https://www.thesolarfoundation.org/national*

project development sectors are $30 and $38, respectively. The median wage for a mid-level assembly or production worker in the manufacturing sector is $20, increasing to $30 for supervisors or foremen." In Pennsylvania, the Department of Labor & Industry, lists the prevailing wage for a solar installer at $41.05/hour with $29.99 of fringe benefits.

3. WORKFORCE DEVELOPMENT

Solar industry professions encompass a wide range of skill sets, education, training and occupational disciplines across the solar supply chain and offers a wide range of jobs at different entry points of experience and education or training. According to the Solar Foundation's Solar Jobs Census, only about two-thirds of solar workers have experience and only one-fifth of companies are requiring a 4-year degree.

In Pennsylvania, many of the solar companies currently train their own workers. There are a handful of available training programs to solar workers. Several colleges and universities across the state teach a variety of programs including solar design, finance and engineering, installation, and solar ecology; the Energy Coordinating Agency in Philadelphia teaches installation skills; and the International Brotherhood of Electrical Workers (IBEW) and the UL offer solar PV training and certifications.

The North American Board of Certified Energy Practitioners (NABCEP) also certifies for PV Technical Sales, Installation Professional, Design Specialist, Installer Specialist, Commissioning & Maintenance Specialist, and PA and Solar Heating System Inspector Certification Programs.[50] NABCEP certification is becoming a standard for training and certification across the nation and there is a moving demand from companies and customers to require workers with NABCEP certification to demonstrate knowledge and capability.

B. STATUTES AND REGULATIONS AFFECTING SOLAR

The pathways to increased solar deployment in Pennsylvania will continue to be affected by existing state and federal policies as well as new policies and strategies. This section seeks to provide a brief review of the significant existing legislation and regulations at the state and federal level.

1. ALTERNATIVE ENERGY PORTFOLIO STANDARDS

In Pennsylvania, renewable energy targets are mandated through the Alternative Energy Portfolio Standards (AEPS) Act.[51] This law requires regulated utilities known as electric distribution companies (EDCs) and competitive non-utility electric generation suppliers (EGSs) to supply 18 percent of electricity through alternative energy resources in 2021. As **TABLE** 6 shows, this is broken down into two tiers with 8 percent of the supply coming from Tier I renewable energy resources (including solar photovoltaic

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50 See: http://www.nabcep.org/certification.

51 Alternative Energy Portfolio Standards, Act 213 of 2004.

generation, wind, conventional hydroelectric generation along with biomass generation from landfill gas) and Tier II coming from "alternative" non-renewable resources like waste coal and coal bed methane. The 0.5 percent that must be generated from solar photovoltaic sources counts toward the overall Tier I goal.

Table 6. Pennsylvania AEPS 2021 Requirements

Tier I			Tier II
Total	Non-Solar	Solar PV	
8%	7.5%	0.5%	10%

Compliance is measured through tracking of Alternative Energy Credits (AECs) and Solar Alternative Energy Credits (known as SAECs or SRECs)[52] through the Generation Attribute Tracking System (GATS) platform managed by PJM Environmental Information Services.[53] One AEC represents one MWh of electricity generated from a qualified alternative energy source and can be purchased separately from electricity. AECs generated anywhere within the PJM region can be used to satisfy the AEPS requirements. On October 30, 2017, Act 40 was signed into law that among other things, seeks to restrict solar eligibility for AEPS compliance to those solar PV systems originating from within Pennsylvania.[54] As seen in **TABLE** 7, there is nearly enough capacity in Pennsylvania alone to satisfy the solar PV requirements from the AEPS, meaning the SRECS generated in other states.[55]

Table 7. Solar demand for Pennsylvania and installed capacity

Year	Generation Requirement (MWh)	Estimated Needed Capacity (MW)	Capacity Installed in Pennsylvania
2015	204,255	179	223
2016	364,442	320	232
2017	419,460	368	294
2018	488,333	429	
2019	562,615	494	
2020	647,152	568	
2021	734,469	645	

[52] In other states these credits are generally referred to as Solar Renewable Energy Credits (SRECs). In this discussion, the term SREC does not exclude Pennsylvania-eligible credits.
[53] https://www.pjm-eis.com/
[54] *See:* Act 40 of 2017 (HB 118). *Note:* At the time this plan was prepared, the implementation of Act 40 is the subject of PUC Docket No. M-2017-2631527.
[55] http://www.puc.pa.gov/Electric/pdf/AEPS/AEPS_Ann_Rpt_2017.pdf

A comparison of regional AEPS/RPS solar goals described in GATS show Pennsylvania, which was a leader in solar in the mid- to late 2000s, has fallen behind. Pennsylvania's solar set-aside increases annually until 2020 – 21 when it peaks at one-half-of-one percent of all energy sold by Pennsylvania's electric utilities. In that year, most neighboring PJM states require a compliance level that is at least several times Pennsylvania's. These range from DC, where the requirement is over three times Pennsylvania's, to New Jersey with a requirement almost seven times that currently set in the AEPS. Maryland reaches the peak of its requirement in 2020 with a 2.5 percent solar goal. Further, most of neighboring states' solar requirements continue to increase after Pennsylvania's levels off in 2020 – 2021. Delaware's reaches 3.5 percent in 2025, New Jersey's advances to 4.1 percent in 2027 and DC's increases to 5 percent in 2032. All these states, having engaged in deliberative processes, arrived at solar requirements for their state that are significantly greater than Pennsylvania's.

There is a cost to ratepayers across the state for operating the AEPS program, who are essentially paying for the required purchase of the solar SRECs, as well as the Tier I and Tier II AECs. However, as shown in **FIGURE** 9, this cost represents well under 1 percent of the average electricity bill in Pennsylvania. This cost is one of the lowest of the restructured states and includes all renewable AECs (Tier I), not only solar SRECs.

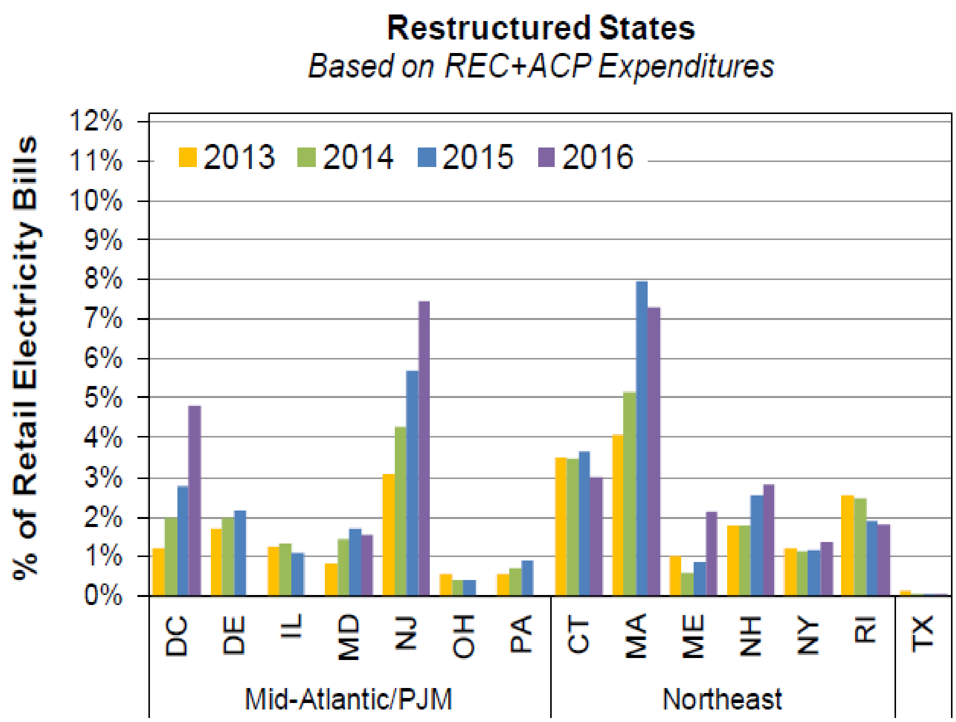

Figure 9. AEPS/RPS Compliance Costs [56]

[56] U.S. Renewables Portfolio Standards 2017 Annual Status Report; Galen Barbose; Lawrence Berkeley National Laboratory, July 2017.

2. NET METERING

The AEPS Act also requires Pennsylvania utilities to offer net metering to customer generators including owners of residential systems up to 50kW and non-residential systems of 3MW (or up to 5MW if additional conditions are met.)[57] Pennsylvania does not have an aggregate cap on the amount of net metered projects that can participate. Under the net metering provision in Pennsylvania, a solar customer-generator receives full retail value in the form of bill credit for all the electricity that is generated by the solar PV system throughout the year, and that any annual surplus of generation is compensated at the “price to compare” value (i.e., includes only generation and transmission, not distribution).

In addition to single-meter net metering there is a virtual meter aggregation option, which allows generation and load at multiple physical meters to be aggregated if all the electric accounts for all the locations are under the same name holder, are located within a two-mile radius of the interconnected solar PV system’s primary location and are within the service territory of the same utility. These limitations on virtual meter aggregation distinguish it from the less restrictive virtual net metering, which is often the billing mechanism for community solar projects. While virtual net metering is generally not permitted in the EDC territories in Pennsylvania, this restriction does not extend to municipalities and cooperatives that are not under the PUC's jurisdiction.

A 2014 study by Lawrence Berkeley National Laboratory concluded that with solar PV penetrations of 2.5 percent by 2020 in the northeast utility scenario, the average rate increase across all ratepayer classes was 0.2 percent. With Pennsylvania’s AEPS solar share requirement set at 0.5 percent penetration by 2021, that would equate to about a 0.04 percent increase in rates due to net metering, assuming all of it was distributed generation in Pennsylvania. This would result in a $100 electric bill increasing by 4 cents.[58]

A follow up study, "Putting the Potential Rate Impacts of Distributed Solar into Context" by Lawrence Berkeley National Laboratory in January 2017, came to the same conclusions of very low costs to ratepayers from net metering billing mechanisms. This is shown in **FIGURE** 10, taken from this study:[59]

[57] Implemented at 52 PA Code Chapter 75, Subchapter B.

[58] Lawrence Berkeley National Laboratory, *Financial Impacts of Net-Metered PV on Utilities and Ratepayers: A Scoping Study of Two Prototypical U.S. Utilities*, September 2014.

[59] Lawrence Berkeley National Laboratory, *Putting the Potential Rate Impacts of Distributed Solar into Context*, (January 2017)

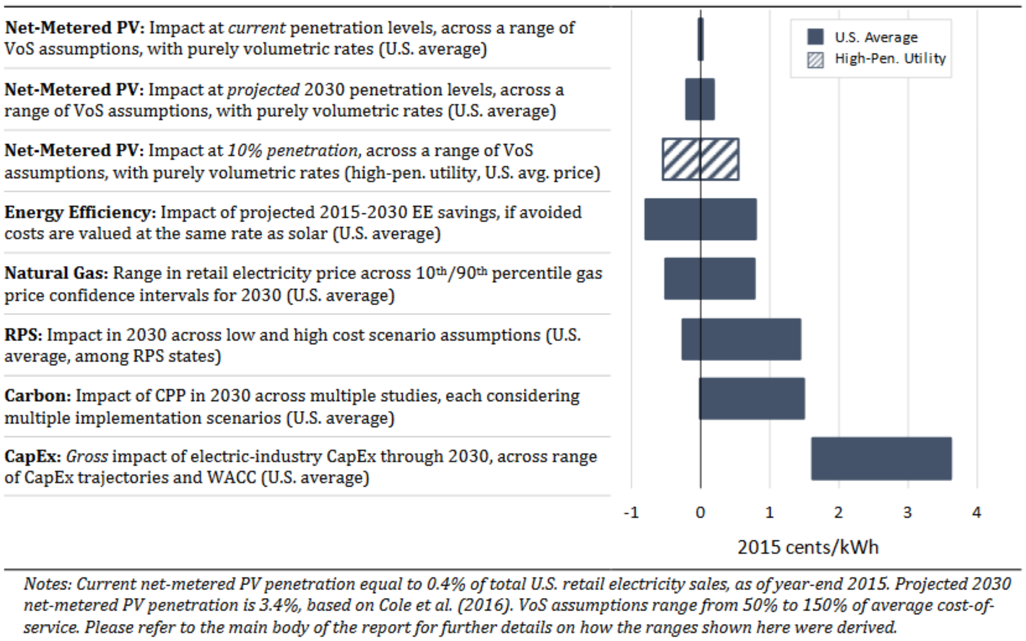

Figure 10. Indicative ranges for potential effects on average retail prices

3. FEDERAL TAX INCENTIVES

Since 2006, the federal Investment Tax Credit (ITC) has provided a credit against federal tax liability equal to 30 percent of the installed cost of solar installations. It applies to residential, commercial and utility investments. Homeowners take this credit when they pay for PV systems installed on their homes. A business or utility may take the credit if it installs, develops and/or finances a project. In 2020 the ITC drops to 26 percent and then to 22 percent in 2021. After 2021, the residential credit is eliminated but the commercial and utility credit will be set at 10 percent permanently. This is exactly when Pennsylvania's current solar requirement under the AEPS is set to reach its limit.

In addition to the investment tax credit for residential and commercial solar, businesses with sufficient tax liability can benefit from the Modified Accelerated Cost Recovery System (MACRS) depreciation schedule allowing depreciation over five years instead of the useful life of the property which may extend up to 35 years.

In addition to MACRS depreciation, in 2015 Congress extended a program of "bonus depreciation" allowing a higher percentage of qualifying capital investments to be depreciated in the first year after purchase before reverting to the MACRS schedule thereafter. This plan allows a 50 percent bonus in 2017, 40 percent in 2018, and 30 percent in 2019 after which the program will phase out barring a further extension by Congress.

4. OTHER CURRENT POLICIES

Act 129 Energy Efficiency: In addition to AEPS, Pennsylvania has the “Act 129” program which requires the Pennsylvania Public Utility Commission to set cost-effective targets for both energy efficiency and peak demand reduction for qualifying utilities.[60] The EDCs then submit for approval program plans to the PUC showing how the targets will be achieved. While solar programs could be integrated into EDC plans, actual impacts are expected to be indirect with Act 129 influencing overall electricity consumption, peak demand, and the price of electricity.

Pending Legislative and Regulatory Activity Effecting Solar: This document is not attempting to catalog potentially relevant legislation introduced at the time of writing. But, the project team notes that there has been significant legislative interest related to renewable energy and energy efficiency in recent sessions. This includes the introduction of bills and/or holding of hearings related to utility ownership of generation and issues surrounding reliability and resilience. While the Project Team is not advocating for, or against, any of these bills, we are also specifically not recommending that legislative activity on these issues be delayed pending the outcome of this project.

C. RELIABILITY, RESILIENCE, AND GRID SECURITY

The Project Team recognizes there has been significant discussion nationally surrounding the related concepts of reliability, resilience, and grid security.

Reliability is the measure of whether electricity sufficient to meet customer demand is capable of being delivered. This can be presented as the percentage of customers experiencing an interruption, the percentage of time delivery is interrupted, the frequency of interruption or other metrics.[61]

Resilience "is the ability to reduce the magnitude and/or duration of [natural or man-made] disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event."[62]

Grid security relates to both concepts as security failures, either cyber or physical, can result in disruption events.

One response to these concerns is to encourage smart-grid technologies that enable deployment of higher levels of distributed generation.[63] However, resilience has also been used as a justification for providing increased funding for selected classes of generation sources that would exclude solar energy.[64]

[60] Act of Oct. 15, 2008, P.L. 1592, No. 129.
[61] See: IEEE, Standard 1366, IEEE Guide for Electric Power Distribution Reliability Indices, (2003).
[62] Dept. of Homeland Security, Critical Infrastructure Resilience, Final Report Recommendations. (Sept. 9, 2009).
[63] See Generally: U.S. Dept. of Energy, Solar Electric Grid Integration (SEGIS) projects.
[64] Grid Reliability and Resilience Pricing, FERC Docket No. RM18-1-000 (2017). (Terminated at 162 FERC 61,012).

VI. MODELING PENNSYLVANIA'S SOLAR FUTURE

The Project Team has used several analytic approaches to help identify and sharpen questions related to Pennsylvania's Solar Future. These have involved scenario modeling to examine the energy, economic, land use, and emissions impacts of solar development. The Project Team has also used customer-perspective financial modeling, and complementary spreadsheet analyses to examine the viability of solar projects from the customer's perspective. The modeling and analyses help assess the need for financial incentives to spur the levels of growth needed to reach the targets.

Modeling helped inform stakeholder discussions by offering preliminary results and analysis to focus the conversation, and by providing a common frame of reference. The modeling has helped answer stakeholder questions and has prompted questions for further investigation and discussion. This is the purpose of the model, to help with understanding and discussion and to point to further work. Modeling the future is inherently uncertain. The model results do not predict the future, but that does not mean they are not useful.

This section of the Report describes the modeling approach and software tools, the scenarios investigated, data sources, and results. More detailed information on each sub-section is provided in Appendix B.

This study does not consider solar only on its own, or even as an isolated element within the electricity system. Instead, the Project Team's investigations consider solar in the context of Pennsylvania's total energy system, across all fuel types and end uses. This approach is useful for examining issues such as emerging trends for electric vehicles and increasing the use of electricity for space conditioning. In many places, solar growth is complementary and related to emerging energy trends. The scenario modeling approach allows us to flexibly examine changes in energy patterns on both the supply and demand sides, including fuel switching and changes in end use efficiency.

The scenario modeling approach provides a flexible platform for considering these types of interactions and questions. The frame of the total energy economy also helps to keep the potential role of solar in perspective, in terms of Pennsylvania's total energy expenditures and investments.

The modeling used two different perspectives for economic analysis:

Economic: The Project Team used a high-level macroeconomic perspective to compare the scenarios' respective effects on the economy. This perspective helps inform economic policy and regulatory decisions. No individual or organization experiences the costs or benefits estimated in this way, but the results can be used to characterize the broader social costs and benefits of alternative-energy futures.

Financial: The Project Team also used customer-perspective microeconomic analyses to estimate the value of investing in solar energy, from the point of view of a home or business.

The customer-perspective financial analyses examine the need for incentives necessary for solar to be a good investment for the customer.

The Project Team used that estimated incentive to calculate the rate impact for all electric ratepayers.

These two approaches complement each other and help to answer questions related to the economic viability and impacts of meeting future solar targets. Individuals considering a solar investment will always use a financial analysis, but policy makers and regulators will need to be informed by a broader economic perspective, in assessing the costs and benefits of a growing solar market in the Commonwealth.

Generally, it is helpful to consider both economic and financial results. In combination, they give a sense of how attractive solar will be for individual investors, and what levels of policy and regulatory strategies might be needed to support the market. Ultimately, the overall benefits to the State's economy, environment, energy security and equity are best considered through a combination of analyses and informed discussions.

A. MODELING SOFTWARE AND METHODS

The PASF Team used two primary software tools, one for each modeling perspective: The Long-range Energy Alternatives Planning system (LEAP; Stockholm Environment Institute) for economic analysis, and the System Advisor Model (SAM; National Renewable Energy Laboratory) for financial analyses. The Project Team also used NREL's Jobs and Economic Development Impact (JEDI) model to estimate job impacts. Using software tools that are publicly available allows interested stakeholders to review and conduct their own analyses.

1. ECONOMY-WIDE MODELING IN LEAP

LEAP is energy policy analysis software[65] designed to compare energy, economic, and environmental effects of alternative energy future scenarios. It is meant for total energy analysis at a relatively large scale but is flexible enough to be applied to different sectors and various levels of detail. The Stockholm Environment Institute has refined LEAP for more than 20 years. It has been used to conduct integrated energy and environmental planning in more than 190 countries.

[65] Heaps, C.G. 2016. *Long-Range Energy Alternatives Planning (LEAP) System*, version 2015.0.24. Somerville, Mass.: Stockholm Environment Institute (USA). https://www.energycommunity.org.

LEAP modeling typically begins with the development of a demand tree that represents energy demand by fuel across end uses and sectors within an economy. **FIGURE** 11 offers an example of the residential portion of a demand tree structure. There are other branches with similar detail for commercial, industrial, and transportation. The Project Team used recent data to create "current accounts," which then became the basis for projected changes in the Reference and Solar scenarios.

The Project Team entered current and projected energy use in the demand tree, across all its branches, to calculate the energy demand by fuel type and sectors. Examples of the type of information entered for each item in the tree are: the amount and type of energy used by end use devices, the level of demand for specific end uses, capital costs, and maintenance costs, and how all those change over time. The structure also reflects demographic and economic activity levels as "demand drivers"; examples are population, household size, value of industrial shipments, commercial employees, and vehicle miles traveled.

Once the demand for various types of energy is determined, LEAP calculates the necessary resources to meet that demand—for example, effects such as transmission losses and availability of generation resources. In this model, LEAP is using 24 time slices for supply and demand analysis: day and night in each month.

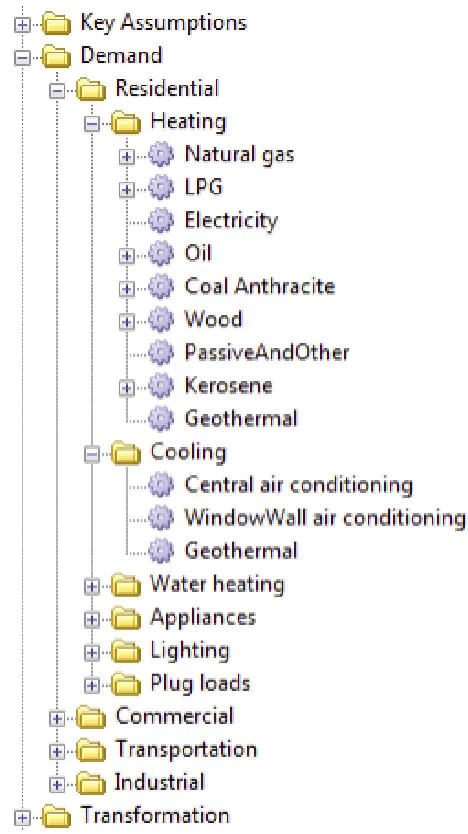

Figure 11. Demand tree structure of LEAP expanded to show residential space

FIGURE 12 shows energy flow in LEAP. Fuel resources at the left move through one or more transitions to serve end uses or end up as losses, at the right. This example is from 2030 in one of the solar scenarios.

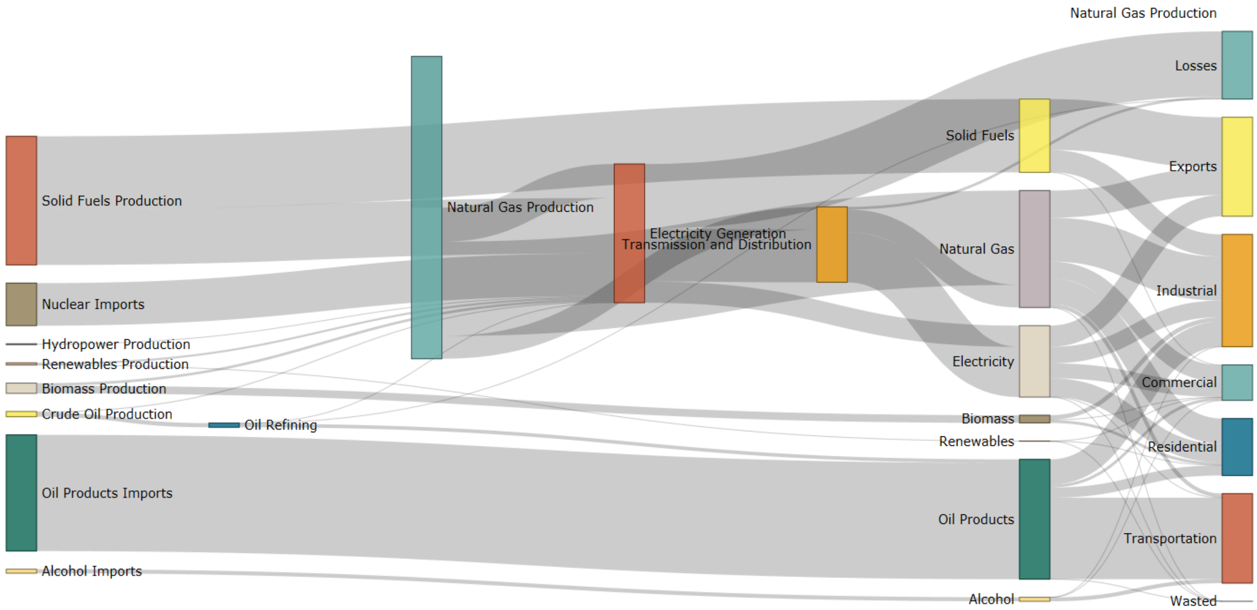

Figure 12. A Sankey diagram of how LEAP uses energy resources to meet total energy demand

2. CUSTOMER-PERSPECTIVE FINANCIAL MODELING IN SAM

For the customer-perspective financial analysis, the project Team used SAM. NREL describes it as follow:

> *SAM is a computer model that calculates performance and financial metrics of renewable energy systems. Project developers, policymakers, equipment manufacturers, and researchers use SAM results to evaluate financial, technology, and incentive options for renewable energy projects. SAM simulates the performance of photovoltaic, concentrating solar power, solar water heating, wind, geothermal, biomass, and conventional power systems. The financial model can represent financial structures for projects that either buy and sell electricity at retail rates (residential and commercial) or sell electricity at a price determined in a power purchase agreement (utility). SAM's advanced simulation options facilitate parametric and sensitivity analyses…NREL provides both SAM and the SDK as free downloads at http://sam.nrel.gov.*[66]

SAM allowed the Project Team to simulate cash-flows for solar projects from the perspective of the owner or financer. These simulations helped estimate incentives necessary for projects to achieve reasonable returns. SAM's advanced analytic capabilities allow the Project Team to consider project financial results across location, scale, capital cost, and incentive level.

B. OVERVIEW OF SCENARIOS

Scenarios are self-consistent story lines of how an energy system might evolve. The term *self-consistent* indicates that energy supplies are sufficient to meet energy demands, including exports and imports.

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[66] NREL. 2014. *System Advisor Model, SAM 2014.1.14: General Description*. https://www.nrel.gov/docs/fy14osti/61019.pdf.

Fundamental economic and demographic drivers can be varied but are also kept consistent when comparing one scenario with another. Scenarios are based on user definition and therefore can analyze and compare a wide range of possible energy futures.

For this study, the Project Team used the LEAP system to create scenarios that reach 10 percent of total retail sales in Pennsylvania from in-state solar power generation by 2030. The Team had identified the 10 percent goal in the original project proposals to the Department of Energy and discussed it extensively with stakeholders during the early meetings. After conducting and refining analyses for more than a year, the Project Team continues to consider the 10 percent by 2030 target to be both ambitious and achievable. The three primary scenarios analyzed in this study are **Reference**, **Solar A**, and **Solar B**.

The **Reference** scenario is "business as usual" and provides a baseline for comparison. It starts with current energy use and projections, and assumes increases in vehicle efficiency, because of Corporate Average Fuel Economy (CAFE) standards, and energy efficiency as mandated by Act 129 and continuing that pace of efficiency beyond the Act 129 period.

In the **Reference** scenario, electricity generation also continues current trends. That is, solar grows to meet the Alternative Energy Portfolio Standards (AEPS) carve out, and non-solar Tier I resources and Tier II resources grow at today's proportions to meet AEPS requirements.[67] The mix of fuels used for non-electric purposes does not change over time.

Solar A and **Solar B** articulate two different pathways for achieving the 10 percent target. The energy consumption in each solar scenario is the same as in the reference scenario. **Solar A** assumes an emphasis on distributed solar, with 35 percent of 2030 solar capacity distributed (half each from commercial and residential customer classes) and 65 percent is grid scale solar. In the **Solar B** scenario, distributed generation makes up only 10 percent of total solar capacity (again, half each from commercial and residential), and Grid Scale is the other 90 percent. Both scenarios require radical growth in grid scale solar.

Solar A also requires significant growth in commercial and residential solar, which would spread the direct benefits of solar among more Pennsylvanians. However, it would also require significant attention to and investment in market design and effective solar deployment.

Table 8 compares the assumptions for each scenario.

[67] Pennsylvania Public Utility Commission, "2015 Annual Report: Alternative Energy Portfolio Standards Act of 2004," Tables 1 and 8, http://www.puc.state.pa.us/Electric/pdf/AEPS/AEPS_Ann_Rpt_2015.pdf.

Table 8. Comparison of the basic assumptions of each primary scenario

	Reference	Solar A	Solar B
Target for in-state solar	0.5% by 2020	10% by 2030	10% by 2030
Total solar capacity in 2030	1.2 GW	11 GW	11 GW
Distributed capacity in 2030	0.6 GW	3.9 GW (35% of total) ½ residential ½ commercial	1.1 GW (10% of total) ½ residential ½ commercial
Grid scale capacity (>3MW) in 2030	0.6 GW	7.1 GW (65% of total)	9.9 GW (90% of total)
AEPS	Assumes AEPS and efficiency trends continue support beyond 2020		
Federal Investment Tax Credit (ITC)	Modeled as a reduction in capital cost. Phased out for residential in 2021 and non-residential in 2023.		

1. ADDITIONAL SCENARIOS

The **Solar A** and **Solar B** scenarios are two paths for reaching 10 percent solar electricity by 2030. The Project Team encouraged stakeholders to consider alternatives that would be worthy of investigation. Many stakeholders supported the following additional scenarios to examine how they interact with solar and how they affect the energy, emissions, and cost results:

- Electrification: More electric vehicles (EVs) and heat pumps
    - 600,000 EVs and 18 percent of residential heat/air conditioning by 2030
- 10 Percent Wind: Wind meets 10 percent of electricity needs by 2030
- High Efficiency: 2 percent electricity savings and 0.5 percent natural gas savings per year
- Solar 8 Percent and Solar 12 Percent targets
    - Created from Solar A and B, by combining the lower of distributed and Grid Scale from A and B for 8 percent, and the higher of each for 12 percent

Results for these alternative scenarios are in Appendix B.

C. DATA SOURCES USED TO BUILD PENNSYLVANIA'S SOLAR FUTURE SCENARIOS

The Project Team collected data from publicly available state level and national sources. The Project Team used information on sources and assumptions in this report and in stakeholder meeting presentations to summarize the modeling inputs and assumptions, and to convey a general sense of the approach and level of depth and rigor of the modeling. Appendix B contains detailed tables of LEAP and SAM model inputs and outputs. The important iterations of the LEAP model will also be retained and available for review using LEAP software, which may be downloaded and used it in read-only mode for free.[68] The Project Team's approach has been a transparent one about inputs or assumptions and involves balancing the need for detail with the risk of overwhelming, confusing, or boring stakeholders.

1. ENERGY DEMAND AND SUPPLY PROJECTIONS

To build the models, the Project Team drew historic information and projections from state and federal sources:

- Employment data and projections from the Pennsylvania Department of Labor and Industry;
- Population and housing data from the U.S. Census American Community Survey;
- Population projections from the Center for Rural Pennsylvania;
- Residential energy characteristics from Residential Energy Consumption Survey 2009;
- Transportation data from Pennsylvania Highway Statistics 2015;
- Fuel costs and transportation projections from the U.S. Energy Information Administration's (EIA's) *Annual Energy Outlook 2017;*
- Commercial and industrial activity from the Pennsylvania Department of Labor and Industry;
- Demand by fuel from EIA's State Energy Data System 2014;
- Electricity consumption projections, by utility, from the 2017 PJM Forecast, which the Project Team extrapolated to 2030;
- Energy supply and generation data and projections from the AEPS *2015 Annual Report*, Commonwealth Economics 2013, Pennsylvania *Comprehensive Energy Analysis*, the Pennsylvania Department of Environmental Protection, the Pennsylvania Bureau of Mining Programs, and the EIA *State Energy Profile,* tables 4, 5, 8, and 10;
- Existing in-state solar capacity from the AEPS database, as of January 2018;
- Generation capacity factors and operations and maintenance costs: NREL 2017 Annual Technology Baseline; and
- Solar prices transition from Pennsylvania-specific data from OpenPV toward national projections from the NREL 2017 Annual Technology Baseline.

The Project Team completed the initial draft of the energy system model in LEAP within six months of project start. Stakeholders made suggestions and corrections through meetings, written communications, and webinars, and by commenting on draft documents. The final inputs and assumptions for both LEAP and SAM models benefited significantly from this review, and from iterative process for refining the models.

2. COSTS

The Project Team has used costs in the models to estimate the investment required to reach 10 percent solar, to estimate the resulting change in annual energy spending, and to evaluate project financials. The models looked at: capital investment in new generation that is added during the model timeframe, grid upgrades required to host additional renewables, the cost of fuels at their end uses (such as gasoline or

[68] See https://www.energycommunity.org to download.

heating oil) and in power plants, and operations and maintenance expenses for at-end uses, renewable generation, and at power plants. The sources and assumptions for cost projections are:

- Electric generation capital and O&M current costs and projections are from NREL's Annual Technology Baseline (ATB).[69]
- Solar capital investment prices start with OpenPV data for Pennsylvania and transition to projected national prices from NREL.

3. SOLAR COSTS AND GENERATION ASSUMPTIONS

Current solar costs are based on Pennsylvania data in OpenPV, and transition to national averages in the National Renewable Energy Lab's 2017 Annual Technology Baseline (ATB). Capital costs for other energy types and operations and maintenance (O&M) costs for all generators are from the ATB's "Mid-cost" case. Capital costs for other energy types and operations and maintenance (O&M) costs for all generators are from the ATB's "Mid-cost" case.

shows the comparison.

Table 9. Comparison of the basic assumptions of each primary scenario

	Residential	Commercial	Grid scale
Capacity factor (DC / AC, %)	14%	12%	16%
(kWh / kW / year)	1,205	1,091	1,433
Capital cost ($ / kW)			
2018 w/o incentive	2,989	2,481	1,373
2018 w / ITC, tariff	2,281	1,931	1,125
2030 (ITC gone)	1,547	1,171	958
O&M 2018 ($ / kW·year)	20	15	12

The Lawrence Berkeley National Laboratory (LBNL) *Tracking the Sun 10* report (2017) shows solar prices in Pennsylvania to be near the national average, especially in years (2010-2013) when more capacity was installed. The Project Team's model inputs reflect premium system pricing currently in Pennsylvania, which is to be expected, given the slower relative pace of solar market development in Pennsylvania in the last several years. Prices are expected to move down to the national average, as installations increase to meet the 10 percent target.

Grid integration costs are based on a meta-analysis of integration cost studies.[70] Costs for individual feeders vary widely, so the extent to which solar can be guided toward more robust feeders can greatly influence the total grid upgrade cost. Given this variability, the same integration cost was assigned to all the solar scenarios, despite the 8 to 12 percent range. The scenarios with more solar do cost more,

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[69] NREL (National Renewable Energy Laboratory). 2017. *2017 Annual Technology Baseline*. Golden, CO: National Renewable Energy Laboratory. http://atb.nrel.gov/.

[70] Synapse, 2015, "A Solved Problem: Existing measures provide low-cost wind and solar integration," http://www.synapse-energy.com/sites/default/files/A-Solved-Problem-15-088.pdf

however, because the cost was entered into the model by per MWh of solar output for the years when solar is growing. Once the 10 percent goal is met in 2030, the Project Team assessed no further integration costs, since the levels of solar stop growing in the model.

Appendix B offers more details about the LEAP scenario modeling and other analyses, and their data inputs, providing documentation on the sources and assumptions used in assessing Pennsylvania Solar Future Targets.

VII. PENNSYLVANIA'S SOLAR FUTURE MODELING RESULTS

The Project Team used quantitative analysis to investigate questions related to the requirements and feasibility of reaching the 10 percent by 2030 solar target. This section presents the main results, addressing the following questions:

- How much solar installed capacity is required to provide 10 percent of Pennsylvania's internal electric demand with in-state solar generation by 2030?
- What is the mix of project types (residential and commercial rooftop or ground-mounted systems) that could be used to meet the target?
- What rates of growth by project type are required?
- Is it likely that the individual project financial returns will make these levels of growth viable?
- From the State's perspective, what are the broader economic costs and benefits of meeting the targets?
- What are the potential job impacts of obtaining the targets?
- What are the land use, siting, environmental emissions, and grid integration impacts?
- How would alternative energy development scenarios, including higher levels of efficiency or greater electrification, affect the solar target results?

Over the course of five formal stakeholder meetings, webinars, and working group conversations, the Project Team has used draft and revised model outputs to inform discussion on these topics. This section summarizes the Project Team's modeling results, addressing these questions. Appendix B presents additional details on the modeling and results.

A. GROWTH REQUIRED TO MEET 10 PERCENT BY 2030

In the three primary scenarios, energy demand remains roughly level during the study period. Electricity demand also maintains a stable share of total energy demand, representing roughly 17 percent of total energy needs. In 2030, total retail electric sales are estimated to be 150.4 TWh. To meet the 10 percent retail electric sales from in-state solar, Pennsylvania must install enough solar to provide 15 GWh of electricity annually by 2030. Given capacity factors between 12 percent and 16 percent for different types of systems, Pennsylvanians must install 11 GW of solar energy by 2030 to meet this goal (**TABLE** 10).

Table 10. Total energy needs, electricity needs, and the necessary response from the Solar A and Solar B scenarios in meeting those needs

Total energy[71]		Electricity	Solar A and B		
Total energy demand (TBtu)		Electricity demand (TWh)	Solar generation (TWh)	Share of electricity from solar	Installed capacity (GW)
2015	2,930	146.9	0.3	0%	0.2
2020	2,995	148.8	2.7	1%	2
2025	2,994	150	6.8	5%	0
2030	2,965	150.4	15.0	10%	11

1. GROWTH IN SOLAR

The growth curves required to meet the 10 percent target are the same for both the **Solar A** and **Solar B** scenario. The difference between the scenarios lies in the mix of the type of solar used to meet the target. The growth curve required to meet the 10 percent solar target **FIGURE** 13 illustrates the need for rapid and continued growth throughout the study period.

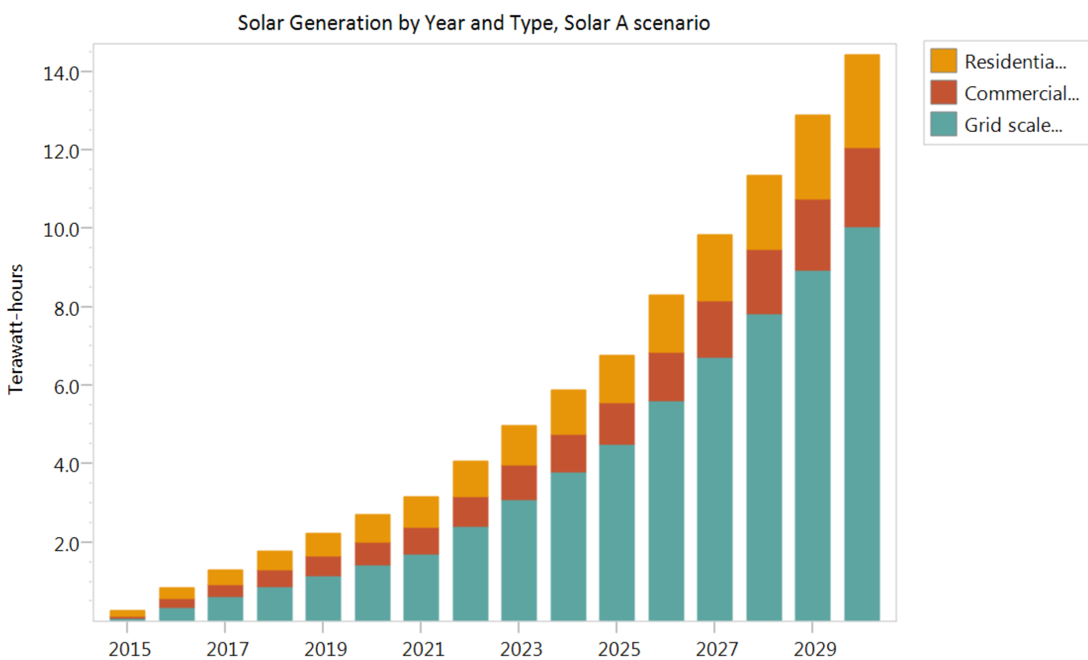


Figure 13. Solar generation under the Solar A scenario, by year and type.

[71] See Appendix C for more information on primary and final energy demands modeled in the scenarios.

2. DIFFERENCES BETWEEN SOLAR A AND SOLAR B SCENARIOS

Although both the Solar A and Solar B scenarios meet the 10 percent target, they use a different mix of solar resources. Solar A contains 35 percent of the generation from distributed (mostly rooftop) solar, whereas Solar B has a lower level 10 percent of distributed solar. In both cases, most of the new solar development is grid scale solar that is connected directly to the transmission and distribution system, rather than behind the customer meter. The following graphic represents the different levels and mix of installed solar capacity in 2030 between the three primary scenarios.

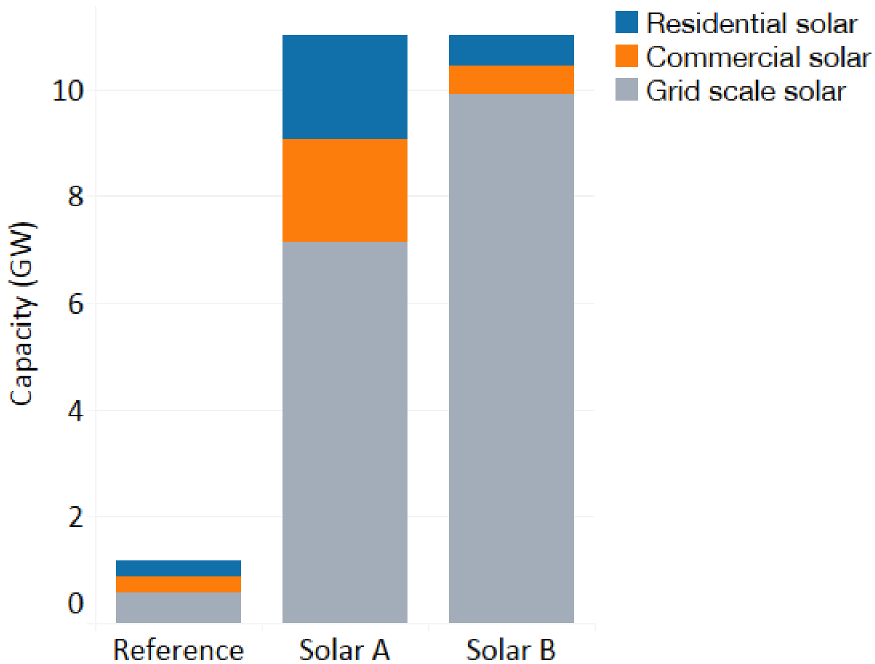


Figure 14. 2030 Solar Capacity by Scenario

Stakeholder discussions have tended to support the anticipated larger contribution to the required growth from grid scale solar represented by both **Solar A** and **Solar B** scenarios.

While there are good reasons to expect a large contribution from grid scale systems, it is also worth noting that even residential roof-top solar has the technical potential to meet virtually all the target, and that cost reductions in time of replacement and new construction could mean this segment could see significant growth as well. Recent research conducted by the National Renewable Energy Laboratory[72] estimates the annual technical potential for residential roof-tops (considering at time of roof-replacement and new construction) in Pennsylvania is 942 MW. This research indicates that the residential time of roof replacement and new construction markets alone, are sufficient to meet the 10 percent target. Further the researchers identify pathways whereby costs for residential roof-top systems could decline dramatically by 2030, dropping from a benchmark of 15.1 cents per kWh in 2017

[72] Kristen Ardani, Jeffrey J. Cook, Ran Fu, and Robert Margolis. 2018. *Cost-Reduction Roadmap for Residential Solar Photovoltaics (PV), 2017-2030.* Golden, CO: National Renewable Energy Laboratory. NREL/TP6A20-70748.

to a range of 5 to 8.1 cents per kWh by 2030. These findings illustrate that multiple market pathways and resources are available and may emerge as Pennsylvania's solar markets evolve.

3. PACE OF SOLAR GROWTH

Another question investigated by the Project Team was how reasonable it is to expect the solar industry can meet the pace of growth associated with meeting the solar target. The solar industry, globally, nationally, and in Pennsylvania has seen exponential growth. For example, **TABLE** 11 presents a seven-year historic compound annual growth rate (CAGR) in Pennsylvania, and a four-year CAGR that covers more recent years with slower installation rates, and the projected rates to meet each solar scenario target.

The seven-year historic CAGR for distributed solar is higher than solar scenarios require. However, the four-year growth rate is closer to the projected rates required to meet the targets, and it would need to be sustained for the next twelve years to meet the targets.

Table 11. Solar capacity annual growth rates, to date and required in the scenarios to meet the 10 percent target

	Residential	Commercial	Grid Scale
2010-2017 CAGR	29%	33%	30%
2013-2017 CAGR	22%	7%	3%
Solar A	20%	17%	33%
Solar B	11%	5%	35%

Grid scale solar would need to maintain a growth rate higher than it has averaged in the past to reach the target. In certain years, grid scale solar has grown more quickly in Pennsylvania, and other markets around the country have seen sustained growth well above the rates required by the solar scenarios.

In both solar scenarios, grid scale grows faster than distributed solar. This is because, Pennsylvania, like other nascent solar markets, has much more distributed solar installed today than grid scale. The solar scenarios have quick growth in grid scale because that sector has driven the growth in most states with more mature solar markets. Under either solar scenario, changes will be required to accelerate grid scale growth.

B. CUSTOMER-PERSPECTIVE FINANCIAL ANALYSIS

Another important topic investigated by the Project Team is given current and projected future market conditions how financially viable are various types of solar projects in Pennsylvania. **TABLE** 12 presents an overview of the financial modeling results for different markets, system types and years in the study horizon.

The results suggest that the financial returns to projects are expected to be favorable. All the cases presented below have positive net present values over the expected system lifetime. They also have expected simple paybacks (for the customer sited systems) of close to 10 years or less, even when there is not an SREC incentive.

For the Philadelphia 2020 residential system and the Mid-State grid scale 2025 system we have also estimated project financials based on some additional incentives. For the residential system this is a solar renewable energy credit (SREC) of $30 MWh for 10 years. For the grid scale system, we examined a tariff of $110 MWh with a 1.9 percent annual escalation, which represents a premium above market level wholesale prices. The feasibility of these levels of incentives are examined later in this section. We note here that the incentives that may be required are rather modest based on the favorable customer financial returns.

Table 12. Costs and values of three types of solar installation, with goals for three regions in Pennsylvania

Market / Year	Type	Installed Cost	Tax Incentives	SREC or Tariff $/MWh	Simple Payback Yr. / IRR	Net Present Value
Philadelphia 2020	Residential roof top	$2.64/Watt	ITC	$0	11.3 yr.	$4,398
				$30	9.8 yr.	$5,295
Mid-State 2025	Grid scale	$1.10/Watt	MACRS No ITC	$110 w 1.9% annual escalation	9.51%	$532,814
Pittsburgh 2030	Commercial roof top	$1.18/Watt	MACRS No ITC	$0	8.2 yr.	$186,420

Further details on the System Advisor Modeling, including parametric results which examine the impact of varying incentives and system costs are presented in Appendix B.

C. RESOURCE SAVINGS FROM REACHING THE SOLAR TARGET

The analyses prior examine the levels of solar growth required to meet the target, and whether considering historic growth rates, and customer financial perspectives the levels of growth are reasonably attainable. Next, we look at what resources are likely to be saved by increased solar generation. These include fuel and operations and maintenance savings from coal and natural gas fired electric plants.

The **Solar A** and **Solar B scenarios** both reduce a similar mix of conventional generating resources to similar levels. Increasing solar generation displaces fossil fuels typically used for electric generation. In Pennsylvania, this includes coal, oil, and natural gas. **FIGURE** 15 illustrates the difference in electricity generation by fuel between the reference and solar scenarios. In the **Solar A and B** scenarios, as compared to the **Reference scenario**, coal and natural gas decrease over time, replaced by solar.

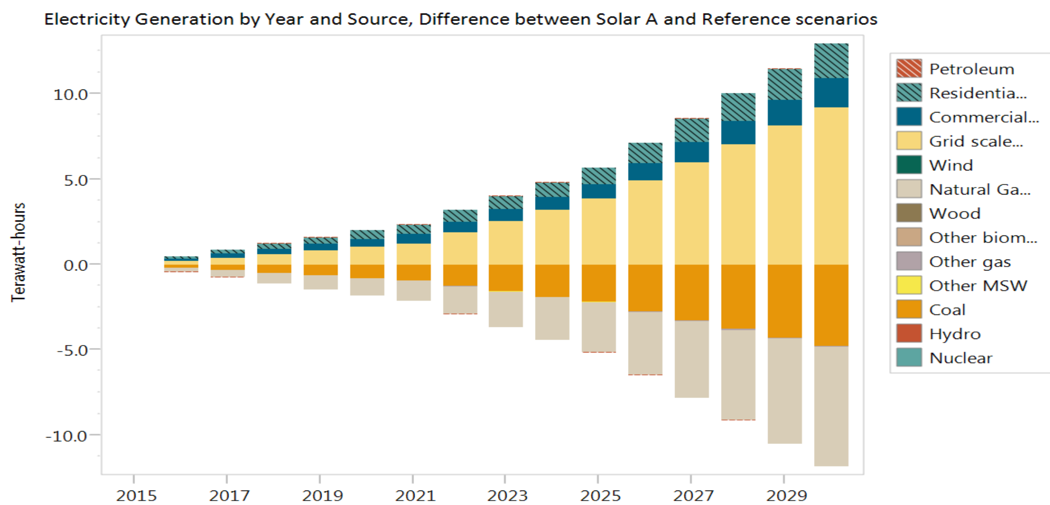


Figure 15. Electricity generation by fuel, solar scenarios vs the Reference case

Looking at the overall mix of generation used to meet total demand the wedge on top illustrates the growth of solar in the total mix (**FIGURE** 16). All scenarios include coal generating capacity declining at 2.1 percent per year until 2030, and nuclear capacity stepping down 819 MW in 2020. These were reasonable inputs at the time the model was built, but the electricity system is evolving rapidly. If additional analysis is performed, these numbers should be updated to include more recent changes including the potential closure of the Beaver Valley nuclear plant. In the solar scenarios, the additional solar generation displaces coal and natural gas generation equally.

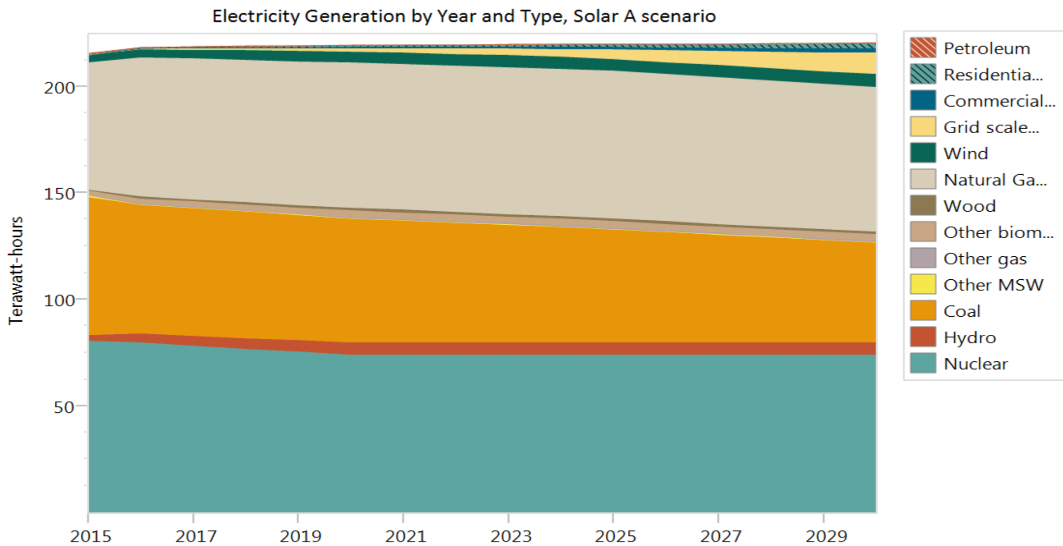


Figure 16. Electricity Generation by Source

The electricity generation profile represented in Figure 16 is based on Pennsylvania's continuing as a significant exporter of electricity. As noted earlier, the projected in-state demand for electricity in 2030 is 150 TWh, and the growth in Pennsylvania based solar generation associated with the **Solar A** and **Solar B** scenarios meets 10 percent of the projected in-state demand.

D. ECONOMY-WIDE EFFECTS OF THE SCENARIOS

The economic results consider the large-scale impacts to the statewide economy. Compared to the Reference scenario, the solar scenarios have higher investments in solar generation and in the transmission and distribution grids to increase hosting capacity and integrate more intermittent renewable resources. Savings from the solar scenarios come from the reduced fuel use and variable O&M costs in fossil fuel power plants. If adding solar avoids the need for new capacity, there would also be capacity savings equal to the avoided capacity cost of the unnecessary plants. However, for this to happen, either PJM capacity market rules or solar performance will need to change. In addition, to the extent that solar can provide ancillary services such as voltage support, it will accrue additional revenues and, possibly, slightly reduce capacity prices. Small scale solar will create some capacity market savings through net demand reduction but that effect, along with other market services, is uncertain and likely small at this scale, so it was not included.

In this section, the results are relative to the costs under the Reference scenario, or business as usual. So positive numbers represent additional costs, while negative numbers represent savings.

TABLE 13 summarizes the economic results over the analysis period. The present value of the additional investments over the period are $10.2 to $11.7 billion. These are offset by roughly $2.4 billion in fossil fuel savings. The net present value of the investments for Solar A and B are respectively $9.3 billion and $7.8 billion more than the reference case, representing higher investments than the reference.

Table 13. Economy-wide net present value (NPV) of the investments of Solar A and Solar B scenarios, relative to the Reference Scenario, excluding externalities, billion 2017 USD, 1.75 percent real discount rate[73]

	Spending or (Savings)	
	Solar A	**Solar B**
Grid upgrades	0.1	0.1
Electricity generation	11.6	10.1
Fuel costs	-2.5	-2.5
Externalities	not included	
NPV (economy wide)	**9.2**	**7.7**
Cost of avoided GHG ($/Tonne CO2e)	29	25

Over 15 years the Solar A and Solar B scenarios have average net annual economic costs ranging from $513 million to $613 million. These estimates represent the lifetime costs and savings associated with the solar capacity in each scenario compared to the reference scenario. One way to put this level of net economic costs into context is to consider that Pennsylvania's annual energy expenditures are roughly $45 billion. Therefore, over the 15-year study period the investments required for the solar scenarios are 1.2 percent to 1.4 percent above current energy spending.

The Project Team suggests the finding that being able to reach Pennsylvania's Solar energy target with net economic costs that are less than 1.5 percent of total annual energy expenditures, indicates the solar transition is economically viable. To illustrate this point, **FIGURE** 17 presents historic increases and volatility in Pennsylvania's total cost of energy expenditures.[74] In this figure, non-electric fuels are represented by the bottom orange segment, and electric expenditures by the second grey colored segment. On top of these two, the Project Team has inserted the small yellow colored segment, visually representing what a net economic cost of $613 million per year would look like in comparison to total energy expenditures.

[73] Real discount rate chosen to be below the 10-year Treasury bill. Discussion of this choice is in Appendix A. Adapted from: Regulatory Assistance Project & Synapse, *Energy Efficiency Cost-Effectiveness Screening*, http://www.synapse-energy.com/sites/default/files/SynapseReport.2012-11.RAP_.EE-Cost-Effectiveness-Screening.12-014.pdf

[74] Energy Information Administration, State Energy Data Sets.

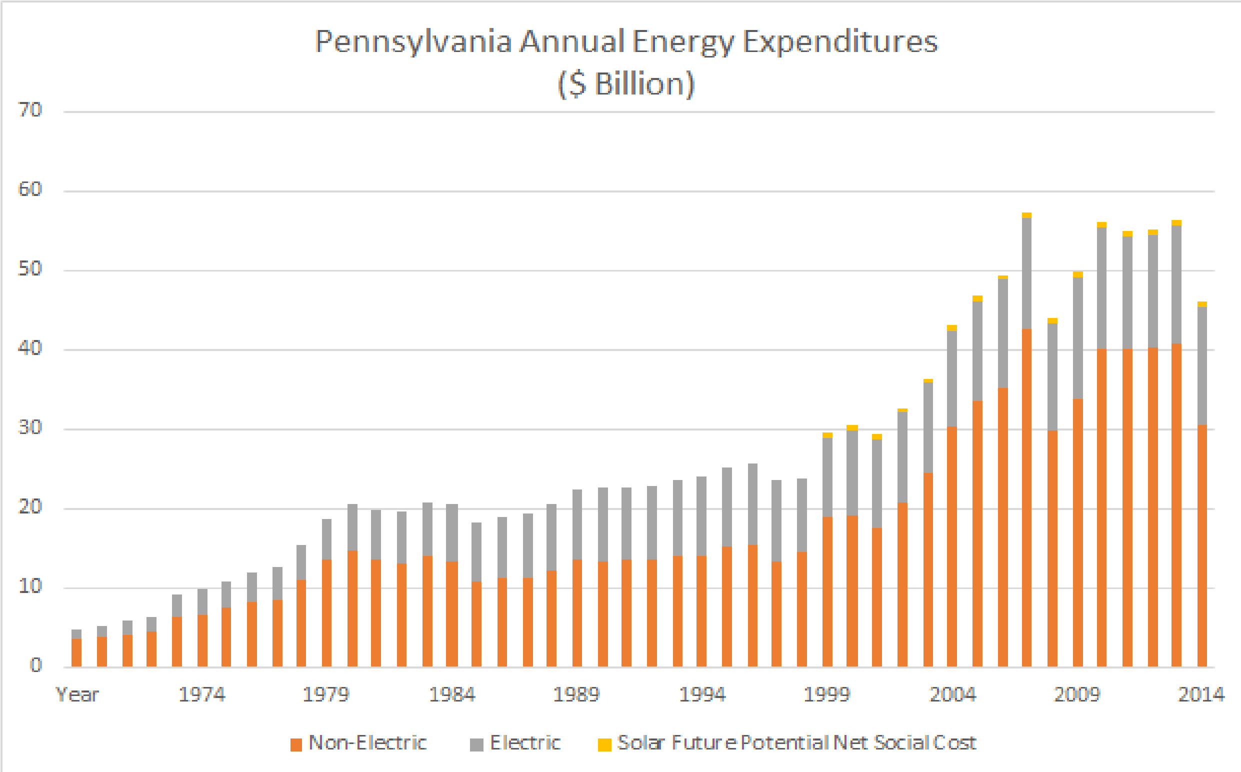


Figure 17. Pennsylvania's annual energy expenditures, 1971 – 2015

E. ECONOMY-WIDE EFFECTS INCLUDING ENVIRONMENTAL COST ESTIMATES

The results in **TABLE** 13 ignore any cost or impact of air pollution, local, regional, or global. As discussed in the Modeling Inputs section of Appendix B, these effects can be included in economic modeling based on the damage the pollutants cost to society, or the cost of compliance that markets have shown emissions can be reduced for. **TABLE** 14 shows the net present investments when including the effect of externalities priced both ways.

Table 14. Economy-wide 2015-2030 cumulative net present value (NPV) of the investments of Solar A and Solar B scenarios, relative to the Reference Scenario, including externalities, billion 2017 USD, 1.75 percent real discount rate[75]

	Spending or (Savings)			
	With damage-based externality costs		With compliance externality costs	
	Solar A	**Solar B**	**Solar A**	**Solar B**
Grid Upgrades	0.1	0.1	0.1	0.1
Electricity Generation	11.6	10.1	11.6	10.1
Fuel Costs	-2.5	-2.5	-2.5	-2.5
Externalities	-34.4	-33.8	-0.9	-0.9
NPV (economy wide)	**-25.2**	**-26.2**	**8.3**	**6.8**

These results show that when accounting for damages to health and the environment, the **Solar A** and **Solar B** scenarios both have net economic benefits in excess of $25 billion over the study period, or more than $1.6 billion of net economic benefit annually. Estimates of environmental externality costs based on compliance costs results in $900 million of additional economic benefits over the study horizon, equivalent to $60 million per year.

The large differences in the economic benefit cost results between the analyses with no externality costs, compliance-based costs, and damage-based costs suggests that current market and regulatory conditions for internalizing the costs of environmental impacts may be falling short of reflecting the long term societal costs and benefits from reduced emissions.

F. ESTIMATING INCENTIVES

The customer financial analysis comparison presented above suggests that some incentives, such as SRECs for the net metered roof top market, or a long-term tariff for grid scale projects may be required to sufficiently increase market activity. The stakeholder meetings have discussed the importance of estimating the possible need for incentives and considering how these might impact utility rates, if as is

[75] Real discount rate chosen to be below the 10-year Treasury bill. Discussion of this choice is in Appendix A. Adapted from: Regulatory Assistance Project & Synapse, *Energy Efficiency Cost-Effectiveness Screening*, http://www.synapse-energy.com/sites/default/files/SynapseReport.2012-11.RAP_.EE-Cost-Effectiveness-Screening.12-014.pdf

common practice any such incentives would be recovered from ratepayers. As the market grows and costs continue to decline it is reasonable to expect the need for incentives will be reduced.

1. SREC SUPPORT FOR RESIDENTIAL ROOFTOP INSTALLATIONS

The Project Team investigated the potential impacts of two possible incentive mechanisms. The first looked at estimating what level of SREC value would provide a residential rooftop customer in Philadelphia with an expected 10-year simple payback in 2025. **TABLE** 15 illustrates the values used in this analysis and the resulting SREC value of $58/MWh. The required SREC value is higher than the $30 SREC value estimated in the financial analysis section above, due to the expiration of the federal investment tax credit in this 2025 analysis.

Table 15. Potential rate impact of SREC incentive, assuming no Federal Investment Tax Credit and 3.75 percent discount rate[76]

	Value
Residential installation cost of PA ($/W)	$2.50
PV system size (kW)	7.5
Total installation cost	$18,750
Assumed solar generation factor (kWh/kW/year)	1.2
Projected annual solar generation (kWh)	9,000
Assumed full retail electric rate ($/kWh)	0.15
Annual electric bill savings	$1,350
Assumed SREC life = target payback (years)	10
Annual SREC payment for payback target	$525
SREC price to achieve target payback ($/SREC)	$58
Customer's NPV after 20 years	$7,000

Next to estimate the potential magnitude of the rate impact from this level of SREC prices, the Project Team analyzed the total cost for SRECs required if customer-sited systems eligible for SREC incentives of $58/MWh account for 35 percent of the proposed 4 percent AEPS goal. This is consistent with the **Solar A scenario** profile (**TABLE** 16).

[76] Real discount rate chosen to be below the 10-year Treasury bill. Discussion of this choice is in Appendix A. Adapted from: Regulatory Assistance Project & Synapse, *Energy Efficiency Cost-Effectiveness Screening*, http://www.synapse-energy.com/sites/default/files/SynapseReport.2012-11.RAP_.EE-Cost-Effectiveness-Screening.12-014.pdf

Table 16. Total cost for SRECs under the Solar A scenario profile for the distributed generation portion by 2025

	Value	Comment
2025 PA electric sales (MWh)	150,000,000	MWh
2025 solar share requirement	4%	
SREC eligible portion of solar market	35%	
SREC requirement	2,100,000	
Calculated SREC price	$58	See previous table
Total incentive cost for SRECs	$121,800,000	
Cost per unit for SRECs ($/kWh)	$0.00081	
Typical PA residential customer electricity use		
Use per year	10,000	kWh/year
Use per month	833	kWh/month
Residential bill impact for SREC		
Cost per year in 2025	$8.17	
Cost per month in 2025	$0.68	

2. TARIFF SUPPORT FOR GRID SCALE INSTALLATIONS

Regarding the remainder 65 percent of grid scale solar installation under Scenario A, the Project Team reviewed modeling prepared by the Mid Atlantic Solar Energy Industry Association (MSEIA). Based on calculating the potential impacts from a grid scale tariff starting at $0.1168/kWh, with 2.425 GW of capacity installed by 2025 under such a tariff, the estimated impact of the grid scale solar penetration part on an average residential bill for the extra costs of the tariff above estimated wholesale market values is $1.08 per month or rounded to .0013 cents per KWh.

The analyses of both types of incentive – SREC payments for 35 percent solar distributed generation and tariffs for 65 percent grid scale solar, and the potential rate impacts suggest electric bill impacts will be modest, at less than $2 per household per month (i.e., $0.68 + $1.08 = $1.76/month).

The incentives and possible rate impacts do not appear in economic analysis because the full price of the solar capacity investments is shown without distinguishing how much is invested by the project owner compared to rate based or otherwise shared.

G. ESTIMATING IMPACTS

1. JOBS

Job impacts of the solar scenarios were estimated using NREL's Jobs and Economic Development Impact (JEDI) model.[77] **TABLE** 17 shows some of the assumptions. Combined with the itemized cost for solar installation and maintenance, the JEDI model uses economic input output analysis to provide an estimate of how much of the investment in solar recirculates within the Pennsylvania, supporting local businesses and jobs.

Table 17. Assumptions for the Jobs Model

Installation Costs	Purchased	Manufactured
Materials & Equipment	Locally (%)	Locally (Y or N)
Mounting (rails, clamps, fittings, etc.)	60%	N
Modules	30%	N
Electrical (wire, connectors, breakers, etc.)	95%	N
Inverter	30%	N
Labor		
Installation	50%	
Other Costs		
Permitting	100%	
Other Costs	100%	
Business Overhead	100%	
Sales Tax (Materials & Equipment Purchases)	100%	
PV System Annual Operating and Maintenance Costs		
Labor	Local (%)	
Technicians	50%	
Materials and Services	Locally (%)	Locally (Y or N)
Materials & Equipment	50%	N
Services	100%	

Solar panels are a very competitive world-wide commodity. They are assumed to be imported, and even purchased from out of state distributors 70 percent of the time. Other equipment, like wires and other electrical parts are assumed to be purchased locally most often, but still manufactured outside of the state.

Half of the installation and maintenance is also assumed to be from out of state. This is a conservative assumption and reflects Pennsylvania's nascent market, and the proximity to a much more developed

[77] National Renewable Energy Lab, "Jobs and Economic Development Impact (JEDI)," https://www.nrel.gov/analysis/jedi/.

solar market in New Jersey. As Pennsylvania's solar market grows, higher local percentages are expected, which increase the local benefits.

The JEDI results in **TABLE** 18 show one of the benefits of Solar A's larger investment in more distributed solar. Those smaller projects cost more per kW largely because they require more labor. That additional expense, paid for by the project owner, results in more solar jobs than Solar B. While the construction jobs refer to actually building a project, those jobs are likely to continue year after year. Unlike a single centralized power plant, this solar capacity will be built in many different projects, so the construction jobs are ongoing in that way as well.

Table 18. Estimated gross new jobs, by scenario

	Solar A	**Solar B**
Construction Jobs	100,604	67,716
Ongoing Jobs	1,086	983

The JEDI model estimates gross job impacts, that is, it does not account for any reductions in other jobs in the energy industry that are offset by solar. That effect is probably minor in the Pennsylvania Solar Future because the solar penetration is not too high, and the nature of the regional market means existing plants may just export more power rather than ramp down when solar is producing.

2. LAND USE

The Project Team also has investigated the land use impacts from reaching the solar targets. Some observers cite the space requirements of solar as a reason for it not to play a major energy supply role. Although sunshine is one of the least dense forms of energy, and siting space might be a limiting factor in cities attempting to become energy self-sufficient, Pennsylvania has more than enough space for solar. Assuming that any grid scale solar would use 8 acres per MW, grid scale solar would use 89 square miles (56,800 acres) in Solar A and 124 square miles (79,200 acres) in Solar B[78]. In addition, 10 percent of residential, and 50 percent of commercial systems are assumed to be on the ground, contributing to land use. Roof-top systems are not included in the land use numbers. **FIGURE** 18 shows how solar land use would increase over time with the increasing solar capacity.

[78] Sean Ong et al., "Land-Use Requirements for Solar Power Plants in the United States" (National Renewable Energy Laboratory, June 2013), http://www.nrel.gov/docs/fy13osti/56290.pdf.

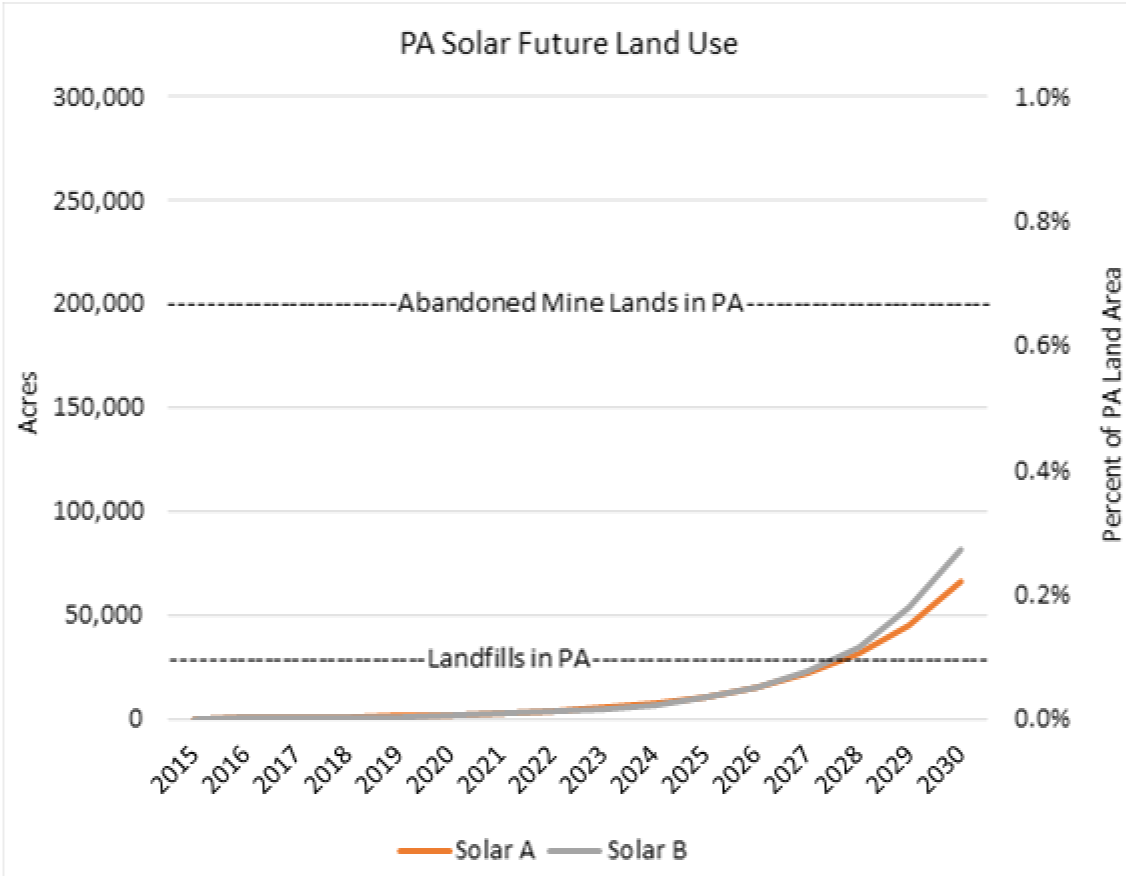


Figure 18. Solar land use by year and scenario

Results indicate that solar land use in the 10 percent scenarios represent a negligible fraction (<3/10ths of 1 percent) of Pennsylvania's total land area of 46,055 square miles. The availability of land for siting solar does not mean that thoughtful land use planning, solar system siting and permitting are not important, but the analysis clearly indicates that the availability of sufficient land to meet the 10 percent target is not a binding constraint.

There are opportunities to site solar development in ways that are complementary to the working land scape and rural economy, such as using solar on buffer zones, disturbed lands, and in conjunction with grazing or pollinator friendly perennials.

3. EMISSIONS

The Project Team identified and applied two methods of assigning environmental costs, one based on compliance markets, and the other based on estimates of damage costs for emissions. The results, when using the damage-based cost method, show that if environmental externalities are counted, there are significant net economic benefits of more than $25 billion of reaching the solar targets over the 15-year study horizon.

However, it is important to note that meeting the 10 percent solar target, does not translate directly to a 10 percent reduction in emissions. This is because electricity represents only about 20 percent of Pennsylvania's total energy use, and emissions. For these reasons, meeting the 10 percent solar target reduces the state's total greenhouse gas emissions by between 2 and 3 percent, as shown in **FIGURE** 19. The graph compares 2030 greenhouse gas emission using 100-year global warming potential by scenario and fuel group. As previously mentioned, electricity remains 17 percent of total energy throughout the study period. Changing 10 percent of electricity to solar amounts to 2 percent of the overall energy system.

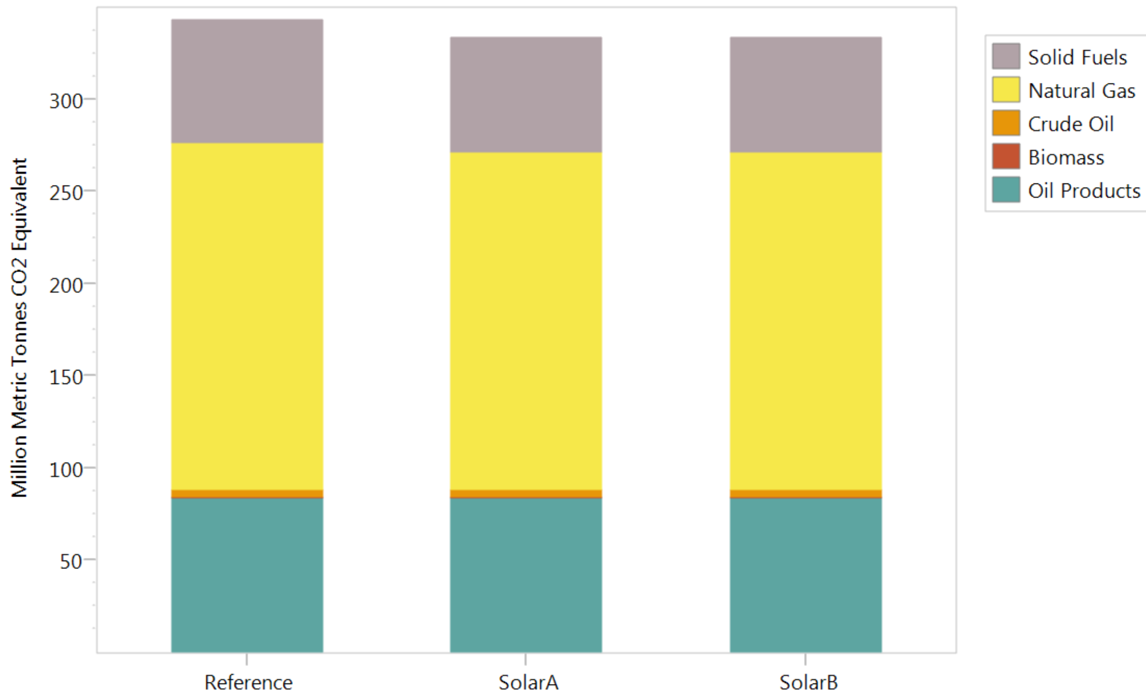


Figure 19. Greenhouse gas emissions in 2030 by scenario and fuel group

H. ALTERNATIVE SCENARIOS

The Project Team developed additional scenarios which built upon the **Solar A** and **Solar B** scenarios to examine additional future energy development options. These scenarios incorporate stakeholder feedback and illustrate tradeoffs between potential future paths. Stakeholders requested scenarios with increased efficiency, electrification, and wind. The Project Team took the following modifications and combined them in a variety of scenarios listed below.

Extra Efficiency: Energy electric efficiency grows at 2 percent annually and gas efficiency grows at 0.5 percent annually, instead of 0.8 percent and 0.1 percent as described in the original scenarios.

Leading states achieve 3 percent savings from energy efficiency programs annually.[79] Six states currently have annual energy efficiency targets of 2 percent or greater[80], and this is not considered out of reach for Pennsylvania.

Electrification: A combination of changes in heat pumps and electric vehicles. Air and ground source heat pumps provide 18 percent of household heat by 2030 and 40 percent by 2050. This change displaces heat currently provided by oil, propane, kerosene, and electric resistance. Additionally, this scenario includes significant increases in electric vehicles from 3,600 in 2017 to 600,000 in 2030. For context, there were over 8,000,000 passenger vehicles in Pennsylvania in 2016.[81]

FIGURE 20 shows the changes in demand for each of the scenario modifications in 2030. The electrification modification is split between the heat pump and electric vehicle modifications.

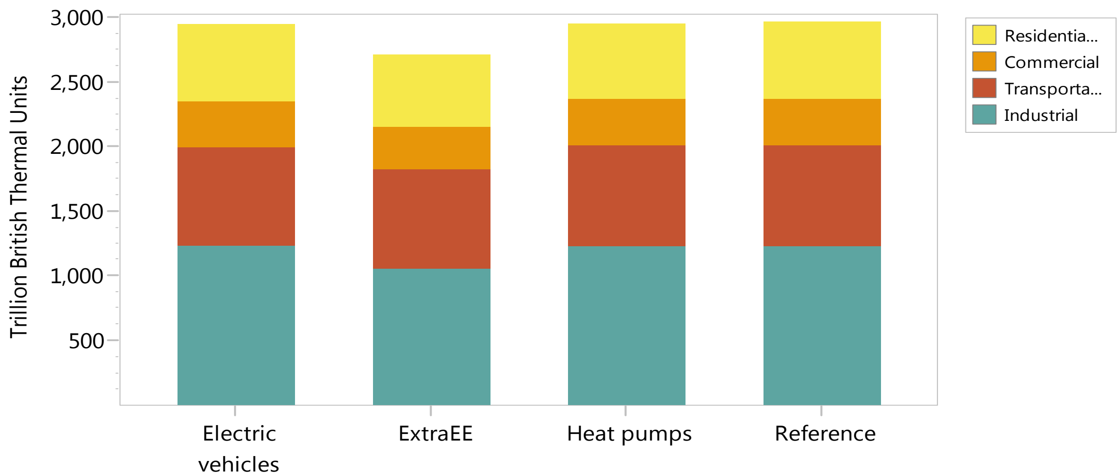


Figure 20. Changes in final energy demand by scenario

Wind: The "Wind" scenario grows wind to provide 10 percent of in-state electricity, like the solar goal. This requires 5.2 GW in 2030, as compared to 1.8 GW in 2030 in all other scenarios. Two checks show this is a reasonable number. One is that 5.2 GW can be reached with a 10 percent compound annual growth rate, which is achievable. The second was a comparison to NREL's Eastern Wind Dataset.[82] That study focuses on integrating high levels of wind generation and includes 7 GW of viable sites in Pennsylvania.

[79] http://aceee.org/sites/default/files/publications/researchreports/u1710.pdf
[80] https://aceee.org/sites/default/files/state-eers-0117.pdf
[81] Pennsylvania DOT, "Report of Registrations," http://www.dot.state.pa.us/public/dvspubsforms/BMV/Registration%20Reports/ReportofRegistration2016.pdf.
[82] NREL, "Eastern Wind Dataset," https://www.nrel.gov/grid/eastern-wind-data.html.

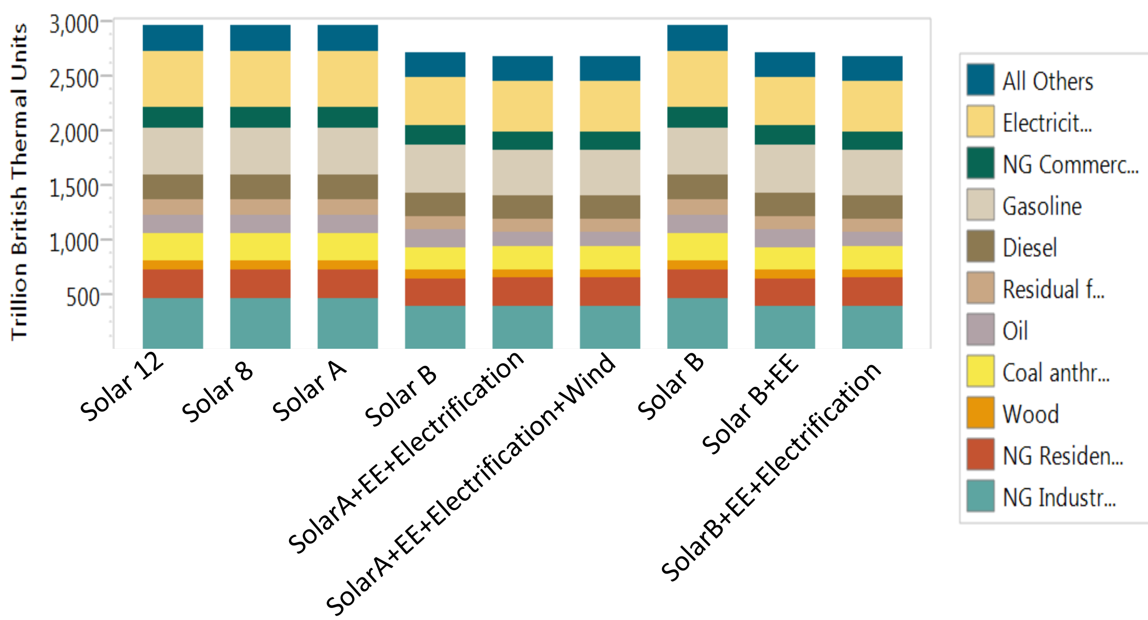
1. ALTERNATIVE SCENARIOS: SUMMARY RESULTS

In total the Project Team developed and analyzed nine scenarios. Detailed results from the alternative scenarios are presented in Appendix B. In this section we present a snapshot overview across all nine scenarios focusing on the final energy demand, and the change in total energy spending.

1 illustrates the final energy demands in 2030 for each scenario by fuel type. The scenarios that include more efficiency and electrification result in demand up to 10 percent lower than energy demand in the reference and **Solar A** and **Solar B** scenarios. The results also show that electrification provides some reduced demand, as electric motors are more efficient than their internal combustion counterparts. However, this impact is relatively modest compared to reductions from efficiency initiatives, primarily because during the study period the saturation of electrification remains relatively small, even though it increases significantly during the study period.

Relative changes in total annual energy spending, as compared to the reference case based on the economic social cost benefit results for all nine scenarios are presented in **FIGURE 22** below.

Figure 21. Final energy demand, 2030, by scenario and fuel



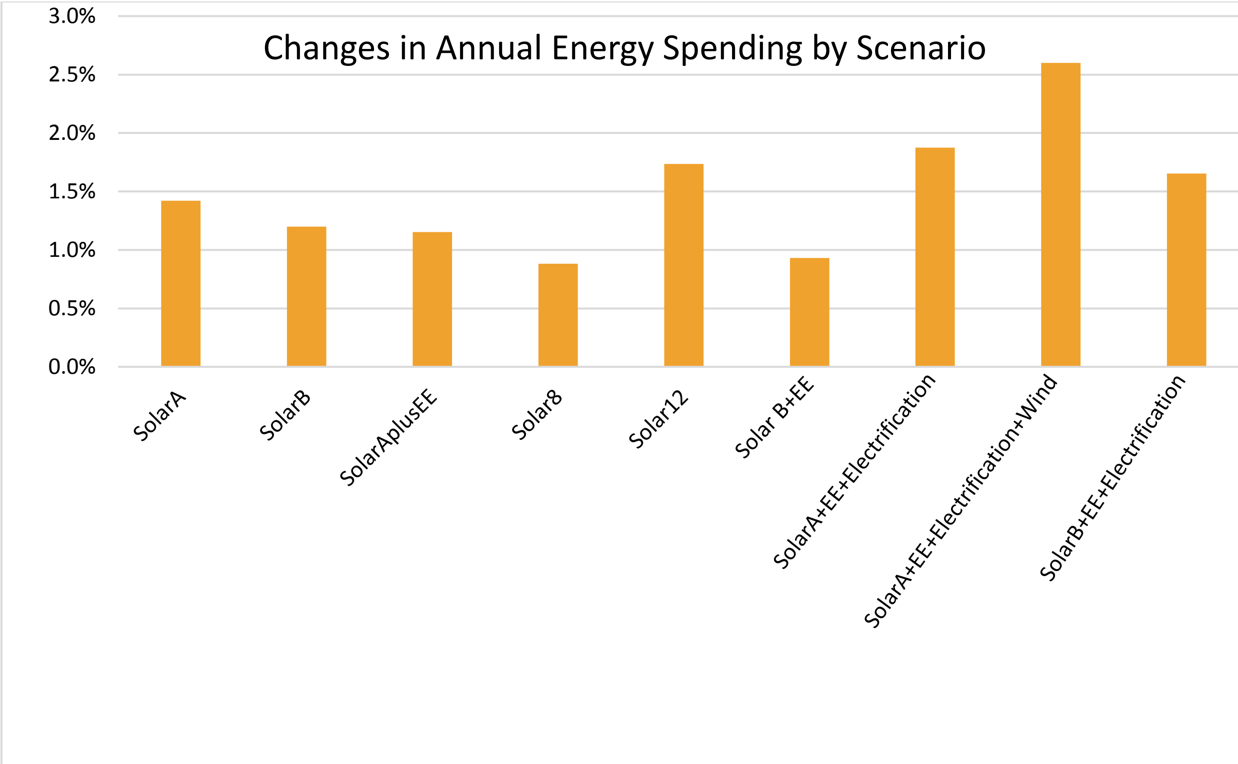


Figure 22. Average annual change in total energy costs, by scenario, compared to Reference

These results illustrate that increased efficiency can help to lower the overall economic costs of reaching the solar target. Integration of higher levels of wind, and strategic electrification are expected to increase costs somewhat (roughly an additional 1 percent annually) in comparison to the Solar Scenarios. Note that in return these scenarios would result in the highest share of total renewable generation in the State and transition to an energy economy with ongoing lower emissions. If emissions externalities are valued based on damage-based estimates, then all the scenarios have large positive net economic benefits and returns.

VIII. PENNSYLVANIA'S SOLAR FUTURE STRATEGIES

The measures detailed in this plan include topics the stakeholder groups identified as affecting growth of solar deployment or shaping market conditions in Pennsylvania over the next decade, and beyond, while considering information provided throughout the project during stakeholder meetings, webinars and modeling data.

The Pennsylvania Solar Future Plan is expected to inform Pennsylvanians of several potential methods for meeting state energy generation goals, resulting in the development of solar deployment strategies that policy-makers may consider. If implemented, these strategies should result in Pennsylvania sited solar electricity generation growing into a higher portion of Pennsylvania's future energy mix. The implementation of a combination of strategies resulting in scenarios, or pathways, will help to begin a transformation of the solar marketplace in Pennsylvania with positive environmental and economic impacts and increasing grid resiliency.

A. OVERVIEW

The Finding Pennsylvania's Solar Future stakeholder engagement process has worked to identify the most impactful and realistic strategies that would move Pennsylvania towards a target of 10 percent solar by 2030. The overarching effort is to identify strategies which will bring the project costs of solar to a price point that will encourage swift adoption of the technology by the market. While there are crosscutting issues reflecting all solar deployment, the approaches and considerations that can help to achieve this goal frequently vary for grid scale and distributed solar generation.

Price is largely affected by tax and trade policy, renewable energy standards, carbon pricing, labor costs and rate structure. Readily available access to capital or long-term financing can produce an environment for which projects are economically feasible at higher price points than when they are absent. In addition, the strategies reflect the desire to incorporate social equity issues the stakeholders identified, including making solar more accessible to low-to-moderate income individuals and to non-profit, municipalities, universities, schools, and hospitals sectors that have no tax equity, protecting natural resources, and addressing climate change. Strategies for tackling other considerations such as mitigating infrastructure barriers are also included.

As demonstrated through the initial modeling, reaching a goal of 10 percent solar by 2030 will likely depend on significantly increasing the amount of grid scale solar deployment in Pennsylvania to a ratio of distributed generation to grid scale generation of 35 percent to 65 percent, respectively, as found in the **Solar A** scenario, or a higher ratio of 10 percent to 90 percent grid scale as found in the **Solar B** scenario. While the scenarios are dominated by a significant build out of grid scale solar in a manner not yet experienced in Pennsylvania, efforts should also be made to overcome barriers for distributed generation and community solar so that Pennsylvanians may maximize the opportunities to develop all solar resources in a manner that increases net benefits. The strategies contained herein recognize that once the barriers are removed for all sectors of solar development, the actual achievable solar penetration could far exceed the goal of 10 percent by 2030.

The pathway to successfully reaching the 10 percent goal will likely require a suite of approaches. This report attempts to identify the most impactful strategies to maximize Pennsylvania's Solar Future. A summary of the strategies is provided below in terms of three categories:

1) Cross-cutting
2) Grid Scale Solar Generation
3) Distributed Solar Generation

The cross-cutting strategies are those that would drastically impact both grid scale and distributed generation, such as changes to the AEPS and adopting carbon pricing. The remaining strategies are focused on increasing either grid scale or distributed generation, reflective of the different proportions of grid scale and distributed solar generation evaluated in the modeling scenarios.

B. CROSS-CUTTING STRATEGIES

1. INCREASE THE AEPS TARGETS AND EXPLORE ALTERNATIVES

The Alternative Energy Portfolio Standard (AEPS) Act of 2004, described in **SECTION V.B.1**, will reach its peak alternative energy and solar targets by 2021, after which the scheduled percentages of electricity sales will be maintained as constants, indefinitely. Since Pennsylvania's requirement of 0.5 percent of generation from PV is significantly less than some other nearby states and therefore the state may be under-performing in solar development, revising the AEPS so that the solar share requirement will continue to increase up to and through 2030 is a workable mechanism for achieving a large penetration of solar development in the state.

> **PROPOSED STRATEGY 1:** Implement an increase in the AEPS PV carve-out to between 4 and 8 percent by 2030 and ensure creditable SRECs are limited to those generated in Pennsylvania wherever possible.

AEPS works by creating a market for non-energy attributes of generation. They key attribute of solar PV generation is measured in SRECs, a quasi-market base tool used by those entities who are required to purchase solar to meet the mandate. SRECs are also purchased by entities like schools, universities, businesses and others who voluntarily purchase SRECs to support solar development for a variety of reasons including but not limited to climate change mitigation. To impact in-state solar deployment, the price of an SREC must be high enough to motivate parties to install solar in Pennsylvania, and not be affected by out-of-state credits being eligible to meet the AEPS solar requirement.

The need to limit out-of-state SRECs

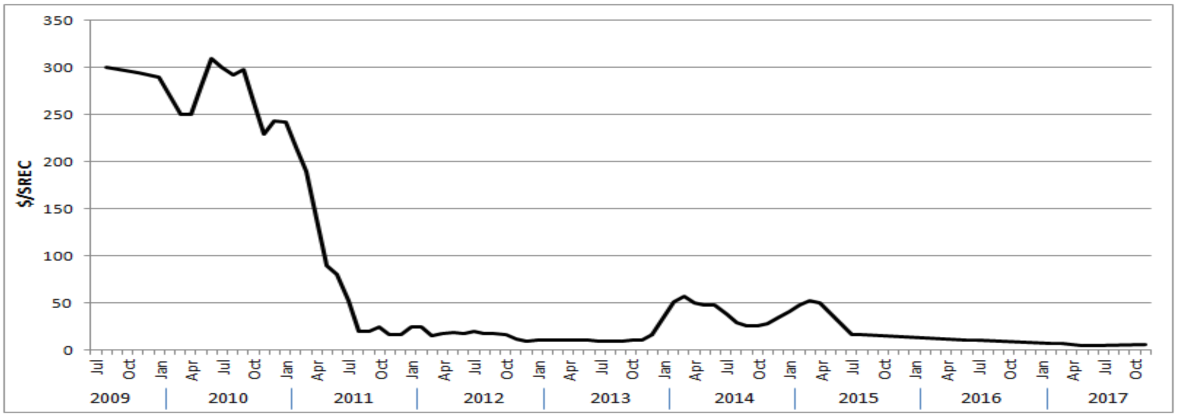


Figure 23. Average Price of Pennsylvania SRECs

As **FIGURE** 23 illustrates, the trend has been towards lower average SREC prices.[83] The initial drop reflects the rapid buildout of solar in Pennsylvania resulting from the PA Sunshine Program from 2010 through 2013 where SREC prices fell from about $300 to about $15. After the PA Sunshine rebate program expired, SREC prices began to rebound through 2015; however, very large solar farms were being developed in other states and selling credits into the AEPS, depressing the SREC price again. In a number of these cases, these states have little or no market for the SRECs themselves so there is no opportunity for PA generators to sell there. During this time period many neighboring states had closed their borders to out-of-state SRECs or limited their acceptance. In Pennsylvania, with an open market border, credits flooded into PA's AEPS marketplace. (see **FIGURE** 24[84]). With a vast oversupply of credits, the value of SRECs was strongly depressed.

[83] Data based on PASEIA Reports and data from SREC aggregators. This is not to be confused with weighted average SREC Prices that are influenced by long-term contracts.
[84] http://www.puc.pa.gov/Electric/pdf/AEPS/AEPS_Ann_Rpt_2017.pdf

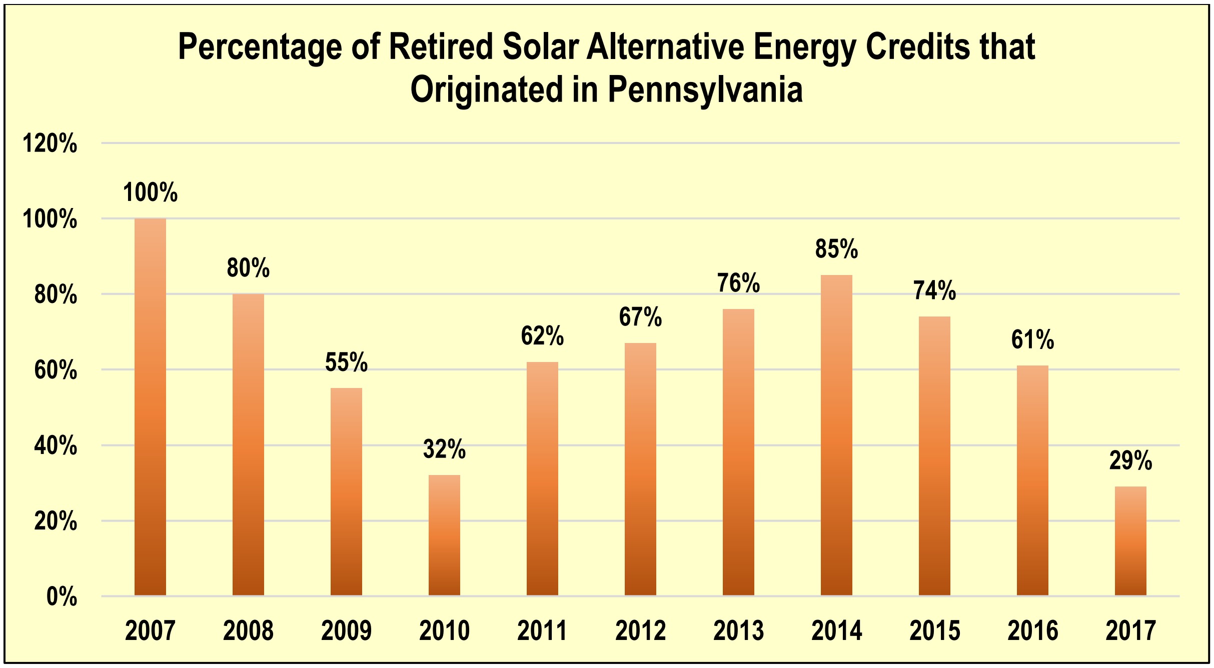


Figure 24. Percentage of retired solar AECs that originated in Pennsylvania

In October 2017, Governor Wolf signed into law Act 40 of 2017 to "close the SREC border" in Pennsylvania. Out-of-state solar generation would only be eligible as renewable energy Tier 1 alternative energy credits (AECs) under the AEPS and not under the separate Solar Share. Exception is made for existing contracts with SREC retiring entities, but not contract renewals. The PUC Final Order implementing this Act is pending.

Arriving at the selected strategy

The selected strategy proposes an AEPS solar carve-out at a lower percentage than the Solar Future Plan's overall 10 percent target. This recognizes that while AEPS has been identified as an important policy solution, the plan does not assume AEPS will be entirely responsible for achieving the goal.

This distinction is necessary, in part, because of underlying differences between AEPS and this plan's target. AEPS requires procedural steps of registering and tracking the use of credits. Should a generator choose not to register credits, or should a purchaser voluntarily retire credits rather than use them for AEPS compliance, a situation could arise where 10 percent of Pennsylvania's consumption is produced by in-state solar PV, but sufficient credits are not available on the market.

There is also a concern if an AEPS solar target is too high relative to neighboring states, higher SREC prices could make paying a Solar Alternative Compliance Payment (SACP) preferable to procuring SRECS. The SACP provision protects ratepayers against price shocks and acts as a price cap set annually to 200 percent of the weighted average market value of SRECs sold through the GATS tracking system.[85]

[85] AEPS Act § 3(f).

The money collected for SACP is then diverted from solar installations to the state's Sustainable Energy Funds to use for renewable energy projects, which may not necessarily increase solar deployment.

Considering the impact to ratepayers

As with any strategy, and particularly strategies directly impacting customer rates, equity issues regarding "who pays" and "who benefits" are primary concerns. Analysis was conducted assuming an increase in the solar share to 4 percent by 2025 for Scenario A, where 35 percent is solar distributed generation and 65 percent is grid scale solar. It assumed an SREC price of $58/SREC with a 10-year payback and net metering benefits for the solar DG market and a tariff-based incentive starting at $0.1168/kWh for the grid scale solar projects. Together, these incentives resulted in an average bill increase of less than $2/month, or about 1.5 percent, for a typical residential customer (assuming 10,000 kWh/yr. usage). This analysis removes the Federal tax credit which will expire after 2021.

2. PROVIDE ACCESS TO CAPITAL

Stakeholders identified access to capital as one of the largest barriers to solar development. Particularly for residential and commercial projects, the lack of available lending products for both residential and commercial customers with adequate terms and low interest rates were identified as barriers to deployment of solar.

PROPOSED STRATEGY 2: Increase access to capital by expanding availability of solar lending products to both residential and commercial projects to enable solar ownership.

Stakeholders identified a preference for ownership models over third-party ownership for residential and commercial projects because they maximize the benefits to the property owner. Third-party power purchase agreements or leasing structures for these sectors which were once prolific in other markets across the country when solar costs were higher were viewed by stakeholders as a less appealing option as the cost of solar has decreased. Alternatively, loans can provide the upfront capital needed to make projects viable and avoid the high upfront costs that third-party financing/ownership model imposes. Therefore, the strategy discussed here is focused on ownership models for residential and commercial clients.

CASE STUDY—ESTES EXPRESS AND PENNSYLVANIA ENERGY DEVELOPMENT AUTHORITY:

Motivated to reduce energy costs, improve efficiency, and reduce environmental impacts associated with their trucking terminal in West Middlesex, Mercer County, PA, Estes Express Lines embarked on a project to design and install a grid-tied solar photovoltaic (PV) project on their approximate 55,000-square-foot roof. The array consists of 2,150 roof-mounted solar modules of 320W each, and is expected to produce over 787,000 kilowatt hours of electricity annually, while significantly reducing carbon footprint.

The total project cost – everything from design and permitting to installation – was $2.05 per watt, or about $1.4 million. The Pennsylvania Energy Development Authority provided a grant to offset $400,000 of their investment, and combined with federal tax incentives and modest Solar Renewable Energy Credits value Estes anticipates a simple payback of about 8.5 years.

Avoiding $66,418 in electric costs also avoids 553 metric tons of carbon emissions. This savings to the environment is equivalent to removing 117 cars from Pennsylvania roads each year. It also reduces the impacts on the electric grid during peak demand, which reduces emissions from less-efficient generation sources.

Many potential solar system buyers are not able to access enough upfront capital for outright purchase. Lending products allow these customers to purchase solar with little or no money down and repay the cost of the system through their electricity savings earned over the first quarter to one-third of the system's life. The Nature Conservancy commissioned a report compiled by the Coalition for Green Capital in 2017 that modeled financing scenarios with varying interest rates and terms for residential and commercial projects in their report. (They assumed an SREC price of $10 per MWh and installation costs of $3.00 per watt for residential systems and $2.50 per watt for commercial systems.) Their modeling "consistently showed numerous scenarios in which it is cheaper for end users to get their electricity from net-metered distributed solar systems than it was to pay for grid electricity"[86] even with a loan. The lower the interest rate and the longer the term of the loan, the lower the levelized cost of energy and the more competitive solar is with other retail electricity sources.

[86] TNC Market Report *at 79.*

PROPOSED STRATEGY 3: Provide loan guarantees to lower interest rates and provide an incentive to deploy solar generation.

The commonwealth has several opportunities to directly influence the availability of long-term financing for grid scale solar energy. The Commonweath Financing Authority has a loan and grant program that can assist solar component manufacturers or developers of solar projects.[87] That program recentley anounced the approval of 78 new projects for 2018. Similarly, a U.S. DOE loan guarantee program, which ran through September 30, 2011, demonstrated that every dollar provided in loan guarantees resulted in $14.25 invested in solar project deployment.[88] Pennsylvania could build on the success or these programs to develop similar programs targeted at grid scale projects.

While enhanced access to capital can take many forms, four possibilities discussed by project stakeholders are presented below:

A) PENNSYLVANIA GREEN ENERGY INVESTMENT PARTNERSHIP

Stakeholders suggested that the state of Pennsylvania establish an Energy Investment Partnership (EIP), commonly known as a Green Bank, to assist in financing the deployment of solar. The Nature Conservancy, recommending the formation of such entities, notes that they "can be capitalized with public funds, philanthropic grants or program-related investments (PRIs), various bond structures, or other forms of private investment which are then used to offer loans, leases, credit enhancements and other financing services for clean energy projects. [And, can] offer a variety of market development services, such as demand aggregation, contractor training, and online clean energy information hubs."[89]

Other stakeholders were concerned that a "Green Bank" is a difficult goal because the likelihood of obtaining the needed resources to start the EIP (*i.e.*, the General Assembly allocating state funds, municipal bond funds or foundation funding, etc.) for its creation seem unrealistic given the large amount of capital that would be needed.

The funding issue could be addressed if the state were to join a carbon regulating program such as RGGI. Other states such as Connecticut and New York fund their EIPs partially with RGGI proceeds.

Assuming funding is available, it was noted that any lending program should include provisions for a marketing plan and other activities that can increase success of the program.

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[87] *See:* https://dced.pa.gov/programs/solar-energy-program-sep/

[88] Mendelson and Kreycik, 2012.

[89] The Nature Conservancy, *Pennsylvania Energy Investment Partnership Report*, 15 (July 6, 2017) *available at:* https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/pennsylvania/energy-investment-partnership-report-2.pdf

B) UTILITY SOLAR LOAN PROGRAM

Allowing regulated utilities (EDCs) to issue solar loans to their customers could potentially allow them to recoup a portion of the revenue lost when customers charged on a volumetric basis increase energy efficiency or install solar generation. At the same time, this could provide low cost solar lending to customers.

In addition, the EDCs have access to capital that may add security to lending, possibly allowing lower interest rates to customers, or attracting private lenders. EDCs also have the advantage over state or county government entities, or even the private lending institutions, as they can market to their entire pool of customers and, if offered with on-bill repayment (discussed below), provide a streamlined process for loan payment that often has higher compliance than private lenders can realize.

CASE STUDY—NEW JERSEY PSE&G:

New Jersey PSE&G's Solar Loan Program allows qualified electric customers to finance a major portion of their solar system and allows repayment in cash or by using Solar Renewable Energy Certificates (SRECs) with a minimum floor price for each credit guaranteed by PSE&G. This program offers customers low out-of-pocket costs to install a solar system and short repayment terms needed to re-coup their investment. While the interest rates are high (more than 11 percent), the program offers guaranteed SREC prices that are created through long-term procurement contracts with SREC providers. As of 2018, over 1,100 business and residential customers finance more than 85 MWdc of solar capacity and the program is about to start their 23rd solicitation phase of the program.

(See https://www.pseg.com/home/save/solar/index.jsp)

Low-income residents may not be able to access lending products at competitive rates because the lenders must account for added risk in their offerings. One possibility that would expand access to capital for these customers is to couple a utility loan program with an interest rate buy-down for residents qualifying as low-income. It is generally difficult for low income customers to qualify for loans. One example of this is the Mass Solar Loan program where the buy-down reduces the annual interest rate 1.5 percent below the typical rate charged by the private lenders.[90] If EDCs would offer solar loans, the PUC could possibly provide permission for rate recovery for the interest rate buy-down.

Such a program would likely need to be voluntary on the part of EDCs and may require legislative action.

C) ON-BILL FINANCING

On-bill financing could provide a streamlined process for customers to repay their loans—whether they originate from the utility or from private lenders—on their electric, gas, telephone or cable utility bills. Repayment using the electric utility bill would normally be the most advantageous because the utility can monitor electricity usage and solar production that could be used to manage an average monthly

[90] http://www.masssolarloan.com/

repayment that aligns with generation and usage. Utilities could partner with private lenders and reduce risk by buying down or securing the loans.

Utilities have been reluctant to offer on-bill financing because it produces extra administrative and equipment/software costs. However, it could allow utilities to earn additional revenue from lending services thus balancing their costs. This would further encourage the customer deployment of solar generation.

Because on bill financing can mitigate some of the risk associated with loans, it broadens customer eligibility and can be particularly beneficial to low-income customers that may not be eligible for a conventional loan or may find a loan too expensive.

Programs can also be designed to further mitigate risk. For example, requiring “bill neutrality”—where the monthly loan payment is equal or less than the prior electric bill—removes the risk of a price-shock to customers and longer-terms or lower-interest rates can further enhance affordability. On-bill payments would be beneficial to institutional, commercial, and residential customers for similar reasons.

The Pennsylvania PUC opened a docket, Docket # M-2012-2289411 and issued a staff report on October 31, 2013 on on-bill finance and repayment. The conclusion of that report was that the electric distribution companies (utilities) would have to obtain permission from the Public Utility Commission to pilot a program. The program would be voluntary and at that time no utility came forward even though both the Sustainable Energy Fund (SEF) and the Pennsylvania Housing Finance Agency submitted to the Working Group two models for discussion. The PHFA model was designed for master-metered affordable housing units and the SEF model was designed for small commercial and industrial customers. Both models envisioned an administrator role, with a net bill impact called bill neutrality, and were expected to align with Act 129 efficiency measures. The Commission-sponsored report and conclusion did not address renewable energy or include solar system purchases. Both entities were willing to put up capital for the pilot, but no further action was taken since no utility volunteered to pilot the program. Incentives for utility participation need to be identified.

D) PROVIDE A LOAN LOSS RESERVE FOR LOW-INTEREST, LONG-TERM SOLAR LOANS

Bank or other lenders have the expectation that a certain percentage of outstanding loans will become uncollectable. These expected losses are typically shown on their cash flow statement or other records where they negatively affect earnings. As such, lenders adjust their underwriting criteria to minimize perceived loan loss risk. This results in fewer high risk borrowers being eligible for loans. For those who qualify, loans tend to be set for shorter terms and at higher interest rates—all factors that discourage deployment of solar.[91]

State or local governments can address this issue and incentivize these projects by providing a loan loss reserve for such lenders. A U.S. DOE SunShot project spearheaded by Citizens for Pennsylvania's Future commissioned a financing white paper for solar financing in 2013 with Clean Energy Finance Center concluded that a loan loss reserve fund of $350,000 would support loans for up to 1,000 households. (.35/watt) at a 10:1 leverage or $175,000 (.18/watt) at a 20:1 leverage per year).

CASE STUDY—CITY OF MILWAUKEE:

The City of Milwaukee's Shines program includes solar financing through a partnership with Summit Credit Union. Utilizing federal ARRA funding, the government provided $100,000 or a 5 percent loan loss reserve pool to leverage at 20:1 a $2,000,000 loan program through Summit at an interest rate range of Prime plus 2.25 percent depending on the term up to 15 years. The loan loss reserve allows the private lending market to manage the loan program that has farther reach than a revolving loan program managed by the City because more loans could be issued, and it avoided the need for a government entity to staff and administer the program and also less expensive than an interest rate buy-down.

(See http://city.milwaukee.gov/MilwaukeeShines/Get-Solar/Solar-Financing.htm#.Wr6vY-gbPIU)

3. ADOPT CARBON PRICING

Carbon pricing is one way to address external environmental costs associated with fossil fuel use and to promote other policy goals. Where carbon prices are adopted, zero-carbon generation such as solar and other clean renewable generation are more cost-effective. Pricing can incentivize installation and investment by private capital. Such programs also generate revenue that can be re-invested in clean generation or directed to other purposes. Implementing such a system in Pennsylvania would likely require legislative action.

PROPOSED STRATEGY 4: Implement a carbon pricing program and invest the proceeds in renewable energy and energy efficiency measures.

[91] *See:* https://www.energy.gov/eere/slsc/rationale-and-goals-loan-loss-reserve-funds

Several models exist for carbon pricing. Broadly they can be categorized as: 1) carbon taxes where governments or other entities set prices per ton of carbon based on some criteria, and 2) emissions trading systems such as cap-and-trade systems where the allowable amount of carbon emissions is fixed, and the market determines the price. (Hybrid models also exist where, for example, the market determines the price up to a pre-set limit.)

In the Northeast, the Regional Greenhouse Gas Initiative[92] (RGGI) program has introduced a carbon pricing system for electric generation, for which nine Northeast and Mid-Atlantic states—Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, New York, Delaware, and Maryland—participate. Virginia and New Jersey may be joining soon. Pennsylvania has been an "observer" in the initiative. The Northeast and Mid-Atlantic states participating in the third RGGI control period (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont) have implemented the first mandatory market-based regulatory program in the U.S. to reduce greenhouse gas emissions.

The 2017 RGGI cap is 84.3 million short tons. The RGGI cap declines 2.5 percent each year until 2020. The RGGI states also include interim adjustments to the RGGI cap to account for banked CO2 allowances. The 2017 RGGI adjusted cap is 62.5 million short tons. RGGI is composed of individual CO2 budget trading programs in each state, based on each state’s independent legal authority. A CO2 allowance represents a limited authorization to emit one short ton of CO2, as issued by a respective state. A regulated power plant must hold CO2 allowances equal to its emissions for each three-year control period. RGGI’s third control period began on January 1, 2015 and extends through December 31, 2017. In August 2017, the RGGI states announced a commitment for an additional 30 percent cap reduction by the year 2030, relative to 2020 levels.[93]

The RGGI states have reduced power sector CO2 pollution over 45 percent since 2005, while the region’s per-capita GDP has continued to grow. RGGI-funded programs also save consumers money and help support businesses. RGGI investments in 2015 are estimated to return $2.31 billion in lifetime energy bill savings to more than 161,000 households and 6,000 businesses which participated in programs funded by RGGI investments, and to 1.5 million households and over 37,000 businesses which received direct bill assistance.[94]

Clean and renewable energy makes up 16 percent of 2015 RGGI investments and 14 percent of cumulative investments. RGGI investments in these technologies in 2015 are expected to return $785.8 million in lifetime energy bill savings to 19,600 participating households and 122 businesses in the region.

RGGI is a well-established and active carbon trading mechanism for which all the Northeast and most of Pennsylvania's neighboring states are participating, which is an example of a successful market-based

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[92] See generally: http://www.rggi.org
[93] http://rggi.org/docs/ProgramReview/2017/08-23-17/Announcement_Proposed_Program_Changes.pdf
[94] http://rggi.org/docs/ProceedsReport/RGGI_Proceeds_Report_2015.pdf

program that has significantly reduced and continues to reduce emissions through a carbon pricing mechanism. Pennsylvania could join RGGI as an active member, or it could work with other states to develop a similar system or develop an independent carbon pricing program

Applying a carbon price to all electric generating units sends a technology-neutral price signal to all generators to reduce emissions without creating preferences for one technology over another. The carbon price also provides cost certainty to all market participants and drives desired behaviors in terms of encouraging emissions-free capacity retention and growth and more efficient operations in the fossil sector.

By itself, carbon price does not provide certainty of emissions reductions and does not ensure that specific levels of desired technology such as solar are achieved. Programs such as renewable portfolio standards better isolate specific desired outcomes (i.e. more solar) but they do not necessarily achieve the underlying policy goal (emissions reduction) at the lowest possible cost because they are not driving economy-wide efficiencies. The project team therefore identifies a strategy not unlike New York, Massachusetts and others, who use a combination of carbon pricing and renewable portfolio standards to increase solar deployment.

Implementing carbon pricing will likely benefit Pennsylvania's nuclear generation fleet by valuing carbon free generation sources. This may slow retirement of existing facilities, but it is not expected to result in new construction. Although all five nuclear facilities in Pennsylvania are all licensed through 2030, the single unit at Three Mile Island is scheduled to retire Sept. 30, 2019, and the two units at Beaver Valley are scheduled to retire in 2021.

4. ADDRESSING SITING AND LAND USE

This report documents that the availability of sufficient land to meet the 10 percent target is not a constraint, but issues around siting and land use remain.

Most parcels in Pennsylvania are divided into 100-acre tracts and so are appropriate for solar systems roughly between 5 and 15 MWs. As a result, larger grid scale projects may require more complicated multi-owner land owner lease agreements which increases costs and lower return on investment. Similarly variations in policies between municipalities can create challenges for solar development.

SOLAR IN PARKS: PENNSYLVANIA DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

The Department of Conservation and Natural Resources is developing solar on state parks across the state. By the end of 2018, DCNR is expected to have over 18 solar installations. These solar arrays could save more than $65,000 a year on electric, reduce 350 tons of CO2 emissions a year (average car emits 6 tons per year) and energy consumption by 600,000kWh per year (average home uses 10,812 kWh per year). Projects like these help state agencies cut both costs and emissions from state operations.

Land use issues go beyond the available tracks. Conservation programs such as Clean and Green and Conservation Reserve Enhancement Program (CREP) and other private conservation programs each have their own rules as to whether solar is restricted in their programs. Developers and owners must research any easements or other restrictions along with any township, homeowner association, or other local government rules for siting solar.

PROPOSED STRATEGY 5: Support the creation and adoption of uniform policies to streamline siting and land-use issues while encouraging conservation.

Consideration should also be given to preserving agricultural land, forest land, and other valuable habitat. Less valuable lands such as landfills, abandoned mine lands, and other brownfields are often better choices to be redeveloped with solar projects. The Project Team notes, however, that brownfield land may provide important open space or developing habitat in certain areas. The Project Team recommends developers coordinate with state resource agencies and local authorities to ensure negative impacts are minimized.

CASE STUDY—PSE&G DEVELOPMENT OF BROWNFIELDS: In New Jersey, the first solar on brownfield projects went into service in 2010 and three others were completed by 2016. Between the projects, there was 52.58 MW of solar capacity on 190 acres of landfill and brownfield space with 175,000 solar panels than can power 8,500 homes. PSE&G reported that landfill and brownfield solar projects are about 40 percent less expensive than typical residential net metered solar projects because of the economies of scale. All projects included streetscaping around the site's perimeters and removed an "eyesore".

There were challenges to developing some of the sites due to the need to do more grading to do construction and in other cases developers had to use special concrete blocks to secure the racking system due to environmental regulations so that the former hazards at the site were not disturbed.

All the approved projects were considered successful and the New Jersey BPU approved an extension of the program to build out 33 additional MW on landfill and brownfields sites over the next three years.

Source: PSE&G Solar Initiative Focused on Landfills and Brownfields by Todd Hranicka, Solar Industry magazine February 2017

5. TAX INCENTIVES

Tax policy, at least in certain cases, is considered implicitly in other strategies such as access to capital and ownership models. The federal ITC for both commercial and residential solar has been an important market driver as well as the MACRS depreciation for commercial solar. While important, and specifically supported by many of the stakeholders, these were not included as strategies in this plan because they operate at the federal level.

There are, however, state tax policies that directly impact solar. For example, while purchase of fossil fuels or electricity for residential, or in many cases commercial, use is exempt from Pennsylvania's 6 percent sales and use tax, the purchase of solar generating equipment is subject to the tax thus raising the cost of a typical residential PV system by approximately $1,000.[95] Similarly, installation of a solar PV system could increase the assessed property value of the home and result in additional taxes. The amount of the tax depends on the assessment and the tax rate established at the county, municipal, or school board level but often results in an effective annual tax rate of between 1 and 2 percent of the property's assessed value.

Pennsylvania also can use its state tax policy to encourage grid scale solar deployment. One possibility is the creation of corporate tax incentives to site solar generation on brownfields as opposed to farmland or forest land. Another is using Partial Property Tax Exemptions, as property tax is one of the more expensive long-term line items for grid scale solar facilities. Reduction in property tax burdens significantly improve project economics, and numerous states offer some type of property tax reduction for large solar energy facilities. Finally, using state investment or Production Tax Credits could also help utility or grid-scale financing. Several states have offered investment tax credits of a limited duration to reduce the upfront cost of renewable energy projects. It will be important to consider the impacts on local governments' revenues.

PROPOSED STRATEGY 6: Evaluate the state tax policy and consider exemptions that encourage the development of solar PV systems.

While tax incentives can be effective, it's not uncommon for solar developers to lack the tax appetite to take full advantage of these programs. In those cases, tax equity structures may be used where, for example, the project sponsor may bring in a tax equity investor as a partner. A percentage of the taxable income and loss is then allocated to the tax equity investor until a certain yield is reached, after which point the sponsor has an option to buy out the tax equity investor's shares at fair market value. The Commonwealth could aid in matching development projects with appropriate investors.

PROPOSED STRATEGY 7: Assist solar project sponsors in identifying investors and/or companies that have sufficient tax equity appetite to take full advantage of the federal ITC and Modified Accelerated Cost Recovery System (MACRS) depreciation if sponsors cannot do so themselves.

C. GRID SCALE SOLAR

As the modeling scenarios discussed above indicate, any significant increase in statewide solar generation is expected to come, in large part, from grid scale units. Even with aggressive deployment of

[95] Legislation has been introduced to exempt solar equipment from sales and use tax. *See* SB 495 (Rafferty).

distributed generation, as much as 65 percent of the solar generation is envisioned to be grid scale to meet the 10 percent goal.

The cost to build grid scale solar has plummeted in the past several years. New unsubsidized grid scale solar assets are signing long-term contracts for energy in the range of $43 to $53/MWh. In comparison, new natural gas combined cycle plants currently require long-term contracts in the range of $42 to $78/MWh.[96] The falling cost of grid scale solar means that it can be a cost competitive generation source even in very low natural gas costs environments such as Pennsylvania.

Still, to acquire capital to build a facility requires financers who are sufficiently confident prices will remain high enough to recoup the substantial upfront investment. In the regulated market setting in which many of the plants serving Pennsylvania emerged, guaranteeing utilities cost recovery from ratepayers over a period of 20 years or more provided this confidence. In the current deregulated landscape however, facilities must compete for short-term energy contracts to serve load. This entails added risk and is reflected in the cost of capital.

Earlier work from the National Renewable Energy Laboratories (NREL) has shown that the critical and effective policies for encouraging grid scale solar include: maintenance of the federal Investment Tax Credit (ITC), availability of low-cost financing, and state renewable portfolio standards.[97] Aside from the changes to the AEPS recommended above, the state has the potential to impact policies supporting availability of financing.

1. LONG-TERM CONTRACTS

Renewable energy projects financed in Pennsylvania typically involve either 1) an entity owning renewable generation and then contracting with an electric distribution company (EDC) for RPS compliance purposes, or 2) a wholesale transaction with a long-term power-purchase agreement (PPA) between a generator and a large customer in PJM along with the sale of Renewable Energy Credits.

Despite ongoing interest in developing projects in PA, Independent Power Producers (IPPs) report that difficultly in securing long-term contracts with utilities is a significant obstacle in building large solar systems in Pennsylvania. EDCs are reluctant to enter into long term contracts (LTC) due to the concern that ratepayers will pay more over time than short term purchases because load growth is relatively flat and energy prices have been stable or declining in recent years. Because long-term contracts are often more readily available in other states, IPPs are more likely to obtain investor financing for these projects outside Pennsylvania where the Return on Investment (ROI) is guaranteed for a longer term.

[96] https://www.lazard.com/perspective/levelized-cost-of-energy-2017/

[97] M. Mendelson & C. Kreycik, Federal and State Structures to Support Financing Utility-Scale Solar Projects and the Business Models Designed to Utilize them, National Renewable Energy Laboratories, (April 2012).

PROPOSED STRATEGY 1: Develop guidelines for limited use of long term contracts (LTCs) for a period of ten or more years to ensure Pennsylvania benefits from grid scale solar energy.

Long-term contracts with large corporate purchasers or directly with utilities allow an IPP to finance projects because those structures decrease the financial risk. The capital is often secured from investors who are seeking to monetize tax equity and/or make a return on their investment over a specific length of time. These long-term contracts provide the assurance to investors that they will be able to recoup their investment and profit from it.

Across the country, many large corporations are currently procuring their own renewable energy generation through PPAs with IPPs. This is a growing market for utility-scale solar energy. In additional, the Rocky Mountain Institute recently reported[98] about the corporate renewable energy market and identified that the small to mid-size business procurement market is also growing with the help of aggregators who pool PPAs with smaller businesses to help pay for the project. These corporate off-takers have not yet emerged in Pennsylvania, but they offer development potential for utility-scale projects.

Under electricity restructuring, Pennsylvania utilities' core functions are to provide distribution and transmission services, providing default service to customers who have not chosen an electric generation supplier, administer low income and energy efficiency programs, and meet AEPS requirements. Utilities do not currently own generating assets.

PROPOSED STRATEGY 2: Evaluate and consider utility ownership of solar generation especially in cases where market-driven deployment may be insufficient to achieve public goals and/or reliability concerns.

At present, the ability of Pennsylvania utilities to own solar generation is not expressly provided for in legislation and has not been directly addressed by the PUC or the courts. Some parties interpret the current rules and regulations to prohibit utility ownership of generation entirely. Other parties interpret the rules to say utility ownership is permissible, but utilities would be restricted to receiving market price and may not include generation in the rate base or receive a guaranteed rate of return. The uncertainty around the legal status of such ownership is, itself, a barrier to utility investment in such resources.

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[98] RMI, *A Buyers Roadmap: Pushing Corporate Renewables to New Heights,* (Nov. 2, 2017) (*available at:* https://www.rmi.org/news/buyers-roadmap-pushing-corporate-renewables-new-heights/).

Appropriate enabling legislation[99], such as PA House Bill 1799 introduced in 2017, could allow utility ownership of solar generation provided such investment is consistent with a utility's obligation to act in a reasonable and prudent manner to provide service to customers at the least cost. Utility ownership could address access to capital issues by financing installation through the utility rate base. This may be implemented as a voluntary choice on the part of customers, particularly those that otherwise lack solar access that opt for utility-owned generation as an alternative to purchase or lease of generation assets. Or, this could be implemented where the utility owns a generation asset to reduce congestion, meet portfolio standards, acquire generation for default-service customers, or achieve other social goals.

In addition to legal issues, specific program design choices could have impacts on other market participants and on energy consumers. While a program could result in a net increase access to solar generation, care must be taken to consider consumer impacts.

Stakeholders' opinions vary as whether to recommend that utilities own solar generation and if so, under what circumstances. Some envision a more limited role for utilities where they would provide solar to low income residential customers, affordable multi-family housing projects or to their default service customers. Others, particularly utilities themselves, prefer more flexibility.

2. GRID MODERNIZATION

Grid modernization encompasses updating the hardware, software and overall functionality of the grid. There is no standardized definition of grid modernization but Grid Wise Alliance in partnership with Clean Edge Navigant conduct a rating of states on a quarterly basis to assess leaders in this area. Pennsylvania ranked 13th in the December 2017 report.[100] States that took a comprehensive approach ranked highest and took actions on energy storage, resiliency and reliability, cyber and physical security and change to regulations including rate design. These actions often included incentives and mandates for energy storage technologies, EV infrastructure and RPS goals.

PROPOSED STRATEGY 3: Investigate opportunities for grid modernization to enable increased solar generation.

More than thirty states plus the District of Columbia now have actions around grid modernization.[101] Of these actions, energy storage is of interest because it can help balance solar on the grid, allow it to qualify as a full capacity resource, and can be dispatched more flexibly than solar alone. When the NC

[99] A bill introduced in the Legislature, HB 1799 (Bullock), would specifically allow for utility ownership, but largely leaves the design issues to the discretion of the PUC.
[100] Grid Modernization Index, November 2017 in partnership with Clean Edge -Navigant
[101] North Carolina Clean Energy Technology Center

Clean Energy Technology Center produced a catalog of actions taken in 2017 they found a significant number related to energy storage.[102]

Storage development is assisted by the recent IRS ruling qualifying certain energy storage projects for ITC treatment. The rise of "smart cities" and initiatives focused on low carbon strategies is also driving the market for energy storage, combined with advances and declining costs for lithium ion batteries, and investments by well-established large businesses according to Navigant Research. In addition, opening wholesale energy markets to storage projects is seen as a key policy development coming out of FERC in February 2018. However, further clarification of what qualifies will be undertaken at their upcoming Technical Conference. These recent actions can provide further support for solar as a flexible resource that can provide greater reliability and security to the grid. As a result, energy storage is expected to grow from 6 GW in 2017 to over 40 GW in 2022.[103]

D. DISTRIBUTED SOLAR GENERATION

The Project Team's modeling scenarios assume distributed solar generation will be responsible for a smaller fraction of the overall deployment than grid scale solar—likely between 10 and 35 percent. While it does not benefit from economies of scale to the same degree as grid scale solar, public demand will support higher costs. The report prepared for the Nature Conservancy by the Coalition for Green Capital finds that "distributed solar is considered 'economically viable' when the levelized cost of energy (LCOE) is below the average retail price of electricity paid by customers. In Pennsylvania, that is about 14 cents per kWh for residential customers and 9 cents per kWh commercial customers."[104]

1. VIRTUAL NET METERING

Pennsylvania's net metering policy is described in **SECTION V.B.2**. A key difference between this and other state programs is that the PUC's interpretation of the statutory requirements recognizes "virtual meter aggregation" as opposed to "virtual net metering." As a result, the regulations include several restrictions: [105] For customers of PUC-regulated EDCs, generation and load at multiple physical meters may only be aggregated if all the electric accounts for all the locations are under the same name, are located within a two-mile radius of the interconnected solar PV system's primary location and are within the service territory of the same utility. The PUC further requires that each meter in the aggregation have load independent of the PV generation system, even though the enabling legislation contains no such restriction.

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[102] NCCTC "The 50 States of Grid Modernization Q1 2017 Quarterly Report

[103] N Carolina Technology Center Grid Modernization

[104] The Nature Conservancy, Pennsylvania Clean Energy Market Report, (Feb. 2017), available at: https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/pennsylvania/pa-clean-energy-market-report-1.pdf ("TNC Market Report').

[105] 52 Pa. Code § 75.11 *et seq*.

PROPOSED STRATEGY 1: Give customer-generators the opportunity to use virtual net metering.

Virtual net metering, on the other hand, is less restrictive and allows for better access to solar and more flexible and cost-effective solar deployment. Virtual net metering permits one or more customers to receive solar generation credit against their electric bills from a solar PV facility that is not tied directly to the customers' meters. This also allows customers who lack access a suitable location to install solar additional options to have access to solar.

States have different approaches to virtual net metering. Massachusetts, for example, makes no distinction in its regulations between conventional and virtual net metering.[106] California, on the other hand has programs that specifically target affordable multi-family housing.[107]

Some stakeholders, such as the utilities and ratepayer advocates, assert electricity customers with net metered distributed generation, such as solar customer-generators, shift costs for the system's infrastructure and maintenance to electric customers without solar PV, or other forms of distributed energy resources (DER). These groups may have advocated for a policy structure where "net-metered customers should be compensated at the wholesale price for the electricity they produce, like other electricity providers."[108] Solar advocates, on the other hand, argue that "most studies have shown that the benefits of distributed solar generation equal or exceed costs to the utility or other customers where penetration is low." [109] And, that cost-shifting is often a mechanism used by regulations to incentivize specific policy goals.

Any implementation of this strategy should be sensitive to the issue of cost-shifting and carefully quantify the values and avoided utility costs resulting from deploying solar to ensure rates continue to be fair and reasonable.

2. COMMUNITY SOLAR

Community solar establishes a shared solar energy resource that participants can jointly own, or subscribe to, and receive benefits in much the same way as if they had installed individual solar systems on their properties. This gives access to solar generation to parties who may otherwise be unable to install a solar system, or lack access to sufficient capital or credit to invest on their own. Programs can also be structured to accomplish specific policy goals such as controlling costs for fixed-income customers or providing low and moderate-income families access to clean generation. As of 2017, over 100 MW of shared solar projects exist across 26 different states.[110]

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[106] Massachusetts, *Net Metering Guide, available at:* http://www.mass.gov/guides/net-metering-guide.
[107] See: http://www.cpuc.ca.gov/General.aspx?id=5408
[108] Edison Electric Institute, *Solar Energy and Net Metering*, January 2016
[109] SEIA & Collaborative of Solar Organizations, *Principles for the Evolution of Net Energy Metering and Rate Design*, May 2017
[110] https://www.communitysolarhub.com/

PROPOSED STRATEGY 2: Identify and remove the barriers to the deployment of community solar systems in Pennsylvania.

Community solar tends to be more cost-effective due to economies of scale. Although there is no inherent limit in system size,[111] most community solar projects are in the range of 1 – 3 MW. Developers find these larger purchases often allow for lower costs of equipment and the centralized location of the project allows for more efficient installation. Locations for community solar systems can also be chosen for optimal generation, lower land-use costs, ease of maintenance, improved security, and other factors.[112] Projects can, therefore, be both cheaper and more productive than equivalent rooftop generation.

The preference of a consumer for solar goods and services can manifest itself in many ways, and individual stakeholders may have different reasons for engaging in a community solar project. Individuals can opt-in for personal reasons, but community solar also affords the possibility of collective action: when a group of individuals act with a common objective that reaches a mutually beneficial goal. In either case, the goal of a project can be lower electricity prices, to generate power locally, to reduce carbon emissions, to potentially increase property values and desirability of neighborhoods etc.

Community Solar for Economically Disadvantaged Communities

Community solar can facilitate the diffusion of solar by expanding access to those with insufficient access to capital or credit for traditional purchase or leasing models. But, while community solar can foster development in low-income areas, simply permitting the community solar model may not be sufficient.

Available investment capital tends to focus on area with the highest return and lowest risk along with low customer acquisition costs. This would normally result in projects targeted at a fewer number of business or high-income residential subscribers before low income communities. Some states have addressed this by adding specific carve-outs in their enabling legislation requiring a mix of projects. In addition, community solar programs can also operate in conjunction with on-bill repayment to reduce risk.

[111] US EPA, Community Solar: An Opportunity to Enhance Sustainable Development (Dec. 2016).
[112] See generally: http://www.communitysolar.psu.edu/

CASE STUDY—PENNSYLVANIA SOLARIZE PROGRAMS

PHILADELPHIA

Solarize Philly is an aggregate buying program intended to lower the price of solar and increase market development. The more customers who sign up as part of Solarize Philly, the more discounts for all participants. Solarize Philly goes beyond the traditional solarize model by adding revenue streams to expand job training programs and to offer an affordable option for low- and moderate-income households, all while providing the best price for all consumers.

The Philadelphia Energy Authority, who manages the program, ensures that the selected installers are reputable, contracts are standardized with key consumer protections, and the equipment is high quality with appropriate warranties. Since its launch in April 2017, over 2,000 households have signed up to receive a free solar assessment through Solarize Philly.

ALLEGHENY COUNTY

Solarize Allegheny ran from February 2015 to June 2017. The initiative helped homeowners and businesses to navigate the solar procurement process by linking them to qualified solar installers and making the process of going solar simple and easy. Solarize Allegheny aimed to double the amount of solar installed across the Allegheny County during the program using on-the-ground community-based marketing and outreach and by partnering with community leaders and organizations.

In 2014, Allegheny County had only 200 solar installations before the program began with just 18 systems installed in the previous year of 2014. During Solarize Allegheny, almost 1,000 people across the county signed up for a solar quote. The program directly resulted in more than 55 people going solar during the program period and the overall county installations increased to 924 during the time. In addition, all installers in the area saw an increase in the number of sales and a large, national solar company opened a branch office in Pittsburgh. Solarize Allegheny was funded by the Heinz Endowments and the Allegheny County Health Department.

Community solar and micro-grids

Micro-grids are local sections of an energy grid that have the capability to disconnect from the rest of the grid and operate in "island mode" autonomously for some period. These can be used to ensure reliability, control costs, or achieve other business or policy goals. To the extent that such grids use solar PV for generation, a project could be structured as a community solar project with the micro-grid functionality adding value. The employment of a micro-grid in this case, might also justify utility ownership or other involvement in the project.

3. ALTERNATIVE RATEMAKING

In Pennsylvania, residential electricity rates are volumetric where much of the costs incurred by EDCs for providing electric distribution services are fixed. This results in concerns that sufficient deployment of distributed generation could result in insufficient revenue for the EDC to maintain reliability or inequitable distribution of costs. This creates a situation where EDCs have financial incentives to limit solar deployment. Increasing fixed charges to customers avoids these issues. However, this step is widely opposed because it reduces the consumer's ability to realize electric bill savings from solar distributed generation, or energy efficiency and conservation measures.

PROPOSED STRATEGY 3: Ensure alternative ratemaking is addressed in a manner that does not create a disincentive for solar deployment.

Recently, Governor Wolf signed House Bill 1782[113] on alternative ratemaking methodologies, thereby allowing the Public Utility Commission to approve the use of alternate ratemaking mechanisms by utilities, such as decoupling, performance-based rates, formula rates and multiyear rates.

Some stakeholders advocate for the general regulatory principle that rates should reflect cost causation. This could result in the use of demand charges for residential customers and use of higher fixed charges to fully recover fixed costs. Other stakeholders maintain that cost causation alone may undervalue externalities such as public health and environmental benefits associated with solar power and that cost shifts inherent in revised rate making may be justified in pursuit of other policy goals.

While the Project Team does not propose any specific rate design be included as a strategy, we note that to the extent a policy-level choice has been made to incentivize solar deployment, rate designs could either support or detract from that goal.

Increases in fixed or unavoidable costs lowers the return on investment in solar systems. For that reason, higher fixed charges or separate demand charges for residential customers could act as a significant disincentive for solar deployment. Demand charges are also of concern because they don't necessarily correspond to the utility system peak demand.

Other suggested approaches, including time-of-use (TOU) rates, net billing (buy all, sell all), and value of solar tariffs have all been explored in different markets and could, depending on implementation, ensure adequate operating revenue for utilities while either incentivizing solar generation or limiting disincentives.

Consideration of Value of Solar is of importance in Pennsylvania both as a possible feature of alternative ratemaking and because the existing law specifies that "Excess generation from net-metered customer-

113 https://www.prnewswire.com/news-releases/legislation-allowing-new-utility-rate-structures-becomes-law-300674475.html

generators shall receive *full retail value* for all energy produced on an annual basis."[114] In spite of this, current net metering regulations result in customer-generators receiving the *full retail rate* when excess generation is carried over month-to-month and only the costs of generation or transmission for annual net generation. There have been several studies conducted across the country over the last fifteen years to assess solar value and the results vary depending on what factors are considered[115] on average the value of solar may be higher than the residential retail rate.[116]

4. PROPERTY ASSESSED CLEAN ENERGY (PACE)

PACE is a mechanism for financing energy efficiency upgrades or renewable energy projects for property owners that allows the owner to finance the project with a private lender and the pay back the loan through the property tax bill. Because PACE loans are land-secured, the loan repayment obligation stays with the property in the event of a sale. This can result in lower finance charges or access to financing for a wider range of individuals or business. This can also reduce the risk that a consumer who invests in energy efficiency or renewable energy and then sells a building will pay a disproportionate share of the cost.

PROPOSED STRATEGY 4: Encourage municipalities to offer PACE programs.

PACE programs may be limited to commercial entities (C-PACE) or to residential customers (R-PACE). Recently, Governor Wolf signed SB 234 which permits, but does not require, Pennsylvania jurisdictions such as municipalities and/or counties to individually create local Property Assessed Clean Energy districts for the commercial, agricultural, and industrial sector (C-PACE).

Having state legislation authorizing PACE is just the first step. Local jurisdictions also need to adopt ordinances permitting PACE obligations and then lenders need to be willing to use the vehicle. One issue that needs to be explored is whether and to what extent PACE results in more lending made available, lower interest rates, longer term loans and changes to underwriting standards.

A 2014 study of R-PACE in California showed PACE financing increased solar installations by 108 percent over the mean watts per owner-occupied household.[117]

There is concern that PACE programs, particularly residential PACE, could encourage predatory lending or other forms of fraud and abuse. Many states have responded by limiting programs to commercial

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114 AEPS Act, Section 5. amended July 17, 2007, P.L.114, No. 35. (emphasis added)

115 A Review of Solar PV Benefit & Cost Studies, 2nd Edition, Rocky Mountain Institute, 2013; https://rmi.org/wp-content/uploads/2017/05/RMI_Document_Repository_Public-Reprts_eLab-DER-Benefit-Cost-Deck_2nd_Edition131015.pdf

116 Value of Solar and Grid Benefits Studies - Alternative Approaches and Results (2014-2016 Era); EUCI NEM Workshop; RAP, 2016; https://www.raponline.org/wp-content/uploads/2016/08/rap-lazar-euci-value-of-solar-studies-2016-july-21-2016.pdf

117 A. Justin Kirkpatrick, Lori S. Bennear, *Promoting Clean Energy Investment: An Empirical Analysis of Property Assessed Clean Energy,* Journal of Environmental Economics and Management (Sept. 2014).

PACE, although best practices guidelines have been developed to address many of the consumer protection issues for residential customers.[118]

5. ADDRESSING INTERCONNECTION ISSUES

There have been some interconnection application issues with solar distributed generation project in most of the EDC regions for various reasons but interconnecting to low voltage distribution service is particularly problematic. Solar PV systems under normal operation, slightly increase the AC voltage at the point of interconnection. In areas served by 4kv distribution lines—in contrast to 13 kV, 34 kV, and higher distribution voltages—the system is particularly limited to how much voltage rise they can tolerate between the substation and the end of the line. Homes or businesses close to substations may have issues with interconnection as higher voltage levels there are required to maintain adequate voltage throughout the circuit. In other cases, homes or businesses further from the substation could have over-voltage issues, like those near the substation voltage due to capacitors, regulators and other devices used to maintain proper voltage levels.

However, “smart inverters” could be a very promising alternate solution at little or no additional cost. Most of the inverters installed today are already smart inverters, which can be programmed to adequately minimize the output voltage or temporarily shut down the inverter if a high voltage threshold is reached. Consequently, there may be some minor loss of solar generation that would offset the electric bill for net metered systems, but this would probably be insignificant in most cases.

PROPOSED STRATEGY 5: Accelerate use of smart inverters to managed over-voltage concerns on low voltage distribution lines and avoid unnecessarily adding costs on small solar distributed generation projects.

Note that programming and/or hardware adjustments needed for the inverter to function in this manner is conducted at the site and does not give the EDC any remote control of the system. However, it is also possible that the smart inverters can be programmed for remote control applications by the utilities, with the customer-generator’s consent (and maybe along with an incentive), or with large grid scale solar facilities. Smart inverters used this way could address some of the concerns and challenges associated with high variable renewable energy integration into the electric grid via sophisticated monitoring and communication of the grid status, the ability to receive offsite operation instructions, and the capability to make autonomous decisions to maintain grid stability and reliability. However, to enable the use of smart inverters in this way in the market, decision-makers must ensure that regulations allow them to be used.

[118] US Dept. of Energy, *Best Practices Guidelines for Residential PACE Financing Programs.* (Nov. 16, 2017). *Available at: https://energy.gov/sites/prod/files/2016/11/f34/best-practice-guidelines-RPACE.pdf*

IX. NEXT STEPS

While a goal of 10 percent of Pennsylvania's consumption being satisfied by in-state generation of Solar PV by 2030 is aggressive given the current status of solar deployment, the Project Team finds that the required generation is within the state's technical and economic potential. While the cost of such deployment represents a modest (less than 1.5 percent) increase in our state's annual energy spending, the combination of fuel savings and accounting for externalities such as avoided public health and environmental damages results in a net benefit of over $1.6 billion annually.

A significant increase in solar deployment will also bring jobs to Pennsylvania. Currently, Pennsylvania lags behind many surrounding states in terms of solar jobs per capita but achieving the 10 percent goal could reverse that trend. The Project team found that more than 60,000 construction jobs would be created as well as many other opportunities in the workforce.

Perhaps the first step to a solar future for Pennsylvania is education. This report challenges the narrative that solar can't work in Pennsylvania and presents 15 strategies suggested by stakeholders to accelerate the deployment of solar energy. This is not an exhaustive list and these strategies can be combined to create many pathways that lead to the 10 percent goal, should our policy makers commit to that path.

During the development of this report there were ongoing legislative and regulatory actions at the state and federal level creating a constantly changing policy landscape. Any set of strategies chosen for implementation must consider these changes. But, a common theme in these changes is a recognition that solar power will increasingly be part of Pennsylvania's future.

This report does not represent the end of the Finding Pennsylvania's Solar Future project. Over the next few months, the Project Team and stakeholders will begin developing the Strategy Support and Market Transformation Plan. This document will describe how the strategies identified in this plan can begin to be implemented, as well as highlight what information is needed to continue to grow solar in Pennsylvania.

X. APPENDICES

A. STAKEHOLDERS

This project would not be possible without an active group of stakeholders. As such, the Project Team would like to recognize and thank the following individuals for their contributions. (*Please Note: Particpation as a stakeholder does not imply endorsement of this report.)*

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B. MODELING

1. INTRODUCTION

The team has used several analytic tools to help inform the Pennsylvania's Solar Future report, working group meetings and discussions. This appendix presents details on:

- Long Range Energy Alternatives Planning System (LEAP) model
- The System Advisor Model (SAM) and the
- Jobs and Economic Development Impact (JEDI) model

And how each of these tools were used to inform the study and the stakeholder discussions. We review the structure and functional objectives for each of the three models, identify data inputs and sources used by the team, review results, and discuss any sensitivity analyses. This appendix presents additional information in the following tables and figures:

2. LEAP MODELING STRUCTURE

LEAP is energy policy analysis software[119] designed to compare energy, economic, and environmental effects of alternative energy future scenarios. It is meant for total energy analysis at a relatively large scale but is flexible enough to be applied to different sectors and various levels of detail. The Stockholm Environment Institute has refined LEAP for more than 20 years. It has been used to conduct integrated energy and environmental planning in more than 190 countries.

The LEAP analyses focused on modeling a future with 10% electricity in state demand being met from in state solar by 2030, with a focus on long term planning and the implications for Pennsylvania's total energy economy, including both supply and demand side resources. The level of detail achieved in the model differed between sectors and was based on best available data at the granularity needed to address the identified focus areas.

LEAP modeling typically begins with the development of a demand tree that represents energy demand by fuel across end uses and sectors within an economy. **Figure 1** offers an example of the residential portion of a demand tree structure. There are other branches with varying levels of detail for commercial, industrial, and transportation. The Team used recent data to create "current accounts," which then became the basis for projected changes in the Reference and Solar scenarios.

The project Team entered current and projected energy use in the demand tree, across all of its branches, to calculate the energy demand by fuel type and sectors. Examples of the type of information entered for each item in the tree are: the amount and type of energy used by end use devices, the level of demand for specific end uses, capital costs, and maintenance costs, and how all of those change over time. The structure also reflects demographic and economic activity levels as "demand drivers"; examples are population, household size, value of industrial shipments, commercial employees, and vehicle miles traveled.

[119] Heaps, C.G. 2016. Long-Range Energy Alternatives Planning (LEAP) System, version 2015.0.24. Somerville, Mass.: Stockholm Environment Institute (USA). https://www.energycommunity.org.

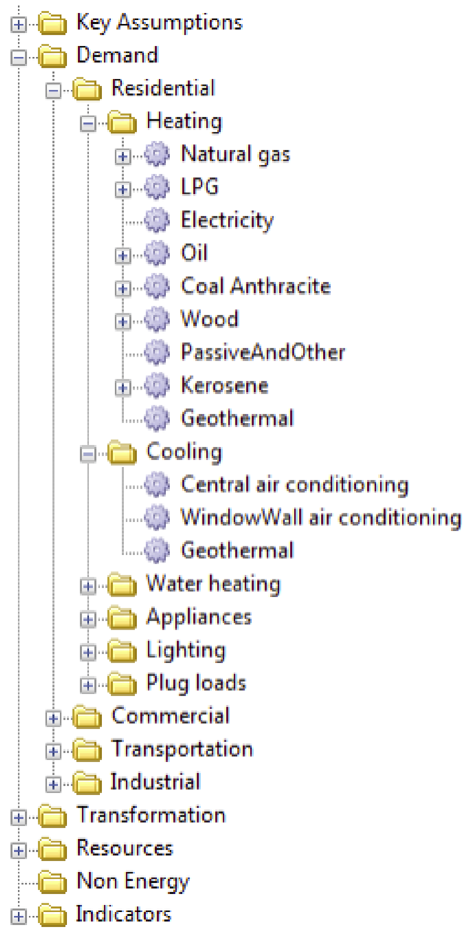


Figure 1. Demand tree structure of LEAP expanded to show residential space

Once the demand for various types of energy is determined, LEAP calculates the necessary energy infrastructure (including for example electric generation plants, and natural gas pipelines) and the natural resources (such as fossil fuel or renewable resources) required to meet that demand. The transformation and resources are used to match demand by time period, as an economy grows, or for example as energy demand varies throughout the year.

Analysts start by defining current accounts which is a snapshot of current energy demand and supply. The tool is structured so that you then develop business-as-usual and comparison scenarios to help investigate possible energy futures. For example, Figure 2 illustrates the Current Accounts for Residential Water Heating. All households have water heating with Natural gas and electricity each representing roughly forty percent of the total market share by fuel type. The input data used to create the current accounts, future years and alternative scenarios are drawn from the Energy Information Administration Residential Energy Consumption Survey, and other state specific sources.

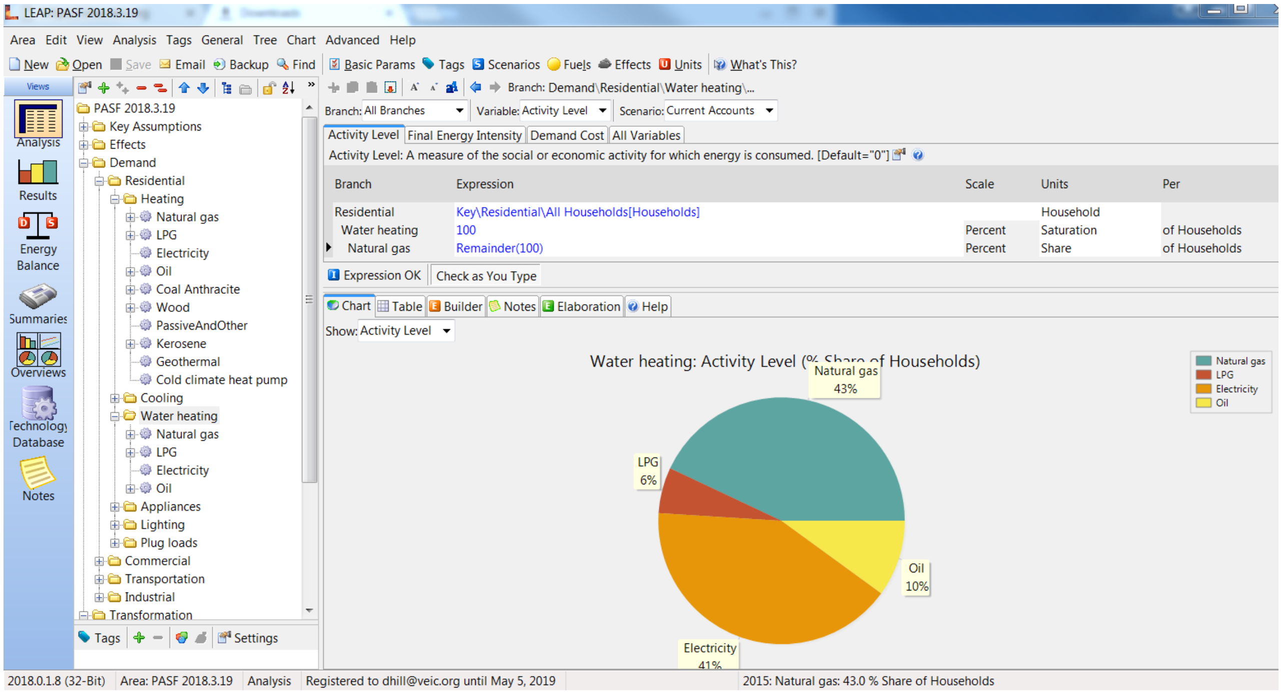


Figure 2: LEAP Current Accounts Input Screen for Residential Water Heating.

LEAP sums the demands by fuel type and by end use for each sector. This allows the analyst to compare the energy use under different scenarios and with different input and data.

For example, Figure 3 below illustrates a comparison of the total final demand by type for residential space heating, comparing the solar A scenario with a scenario that includes higher levels of energy efficiency and more strategic electrification of space heating. The first chart illustrates the total energy use in the Solar plus EE plus electrification scenario and illustrates the total amount saved because of efficiency and electrification. The second chart Figure 4, further examines this difference of roughly 40 Trillion BTUs, identifying the savings by fuel type as well as indicating the increased use in geothermal and cold climate air source heat pumps.

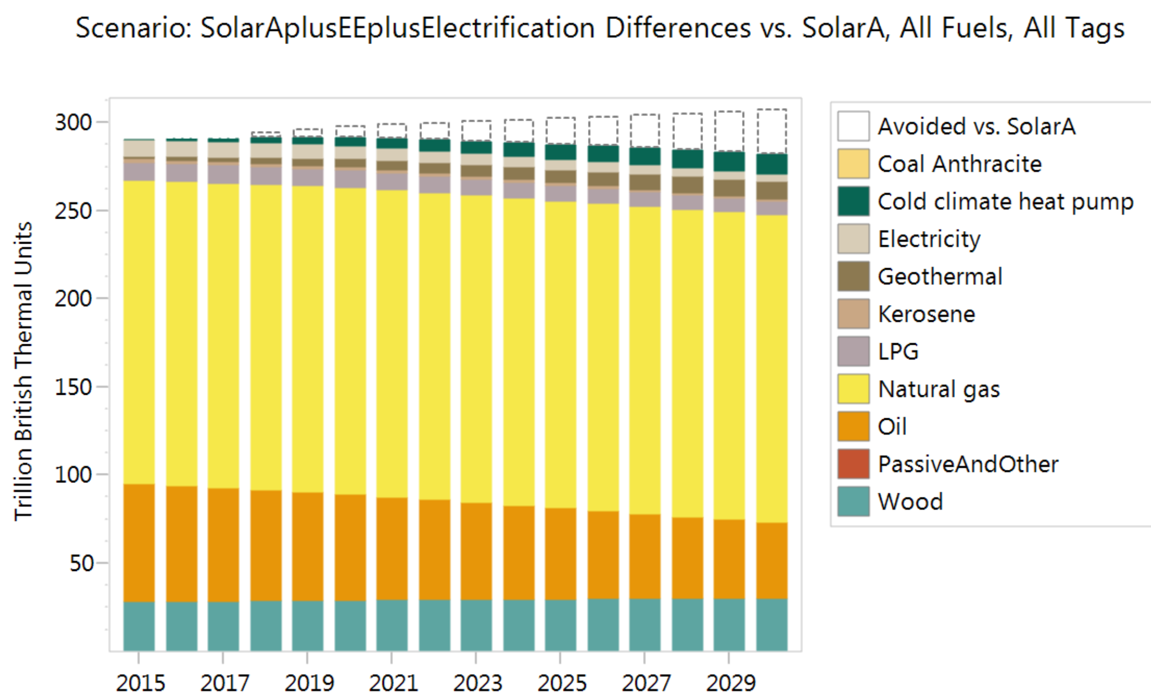


Figure 3: Residential Space Heating, Comparison of Total Energy Demand for Residential Space Heating between Solar Scenarios with and without Additional Efficiency and Electrification of Space Conditioning

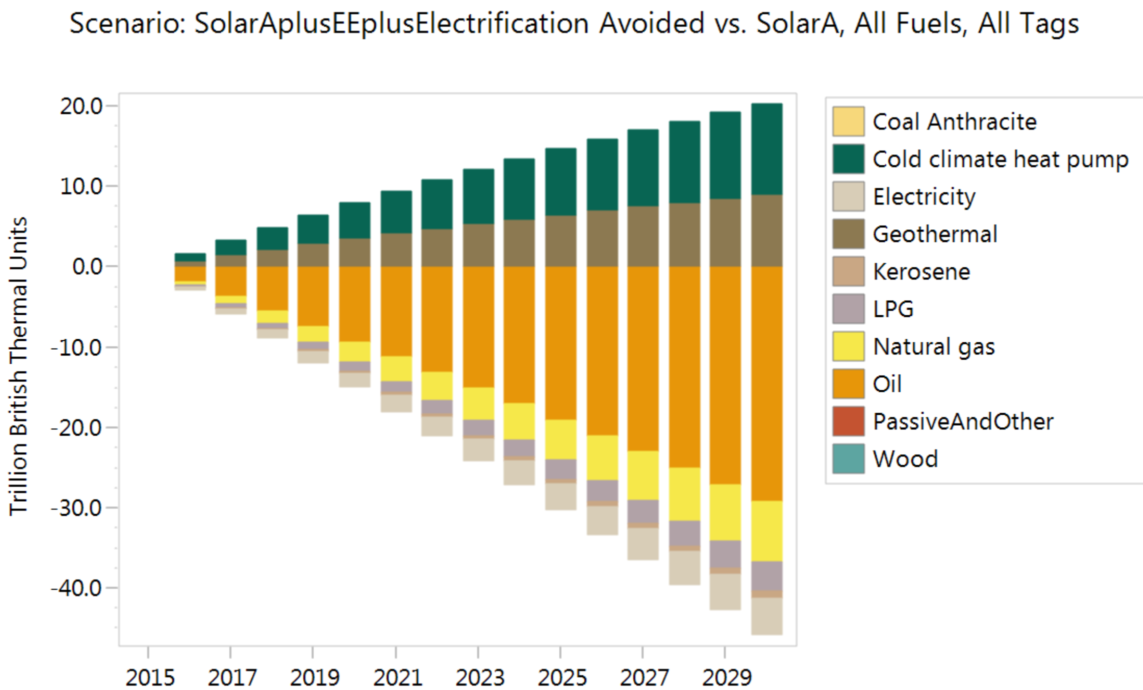


Figure 4: Residential Space Heating, increase in cold climate heat pumps and geothermal and decline in oil, natural gas, and kerosene. SolarAplusEEplusElectrification compared to Reference.

Once the demand for various types of energy is determined, LEAP calculates the necessary resources and to meet that demand. The transformation module in LEAP accounts for losses from the energy production facility to the end user, including transmission and distribution losses for natural gas and electricity.

Electric generation is defined by plant type, with each plant type having input fuels, conversion efficiencies, maximum availability, operating and capital costs. Dispatch order is also specified. For the Pennsylvania's Solar Future Study, the team used merit order dispatch, specifying that when solar and other intermittent resources were available they were dispatched first to meet loads. Scenarios can then vary inputs for the generation plants defined in the transformation module.

As an example, Figure 5 illustrates a comparison between the reference and four of the solar scenarios in terms of the annual energy generation by system type in 2025.

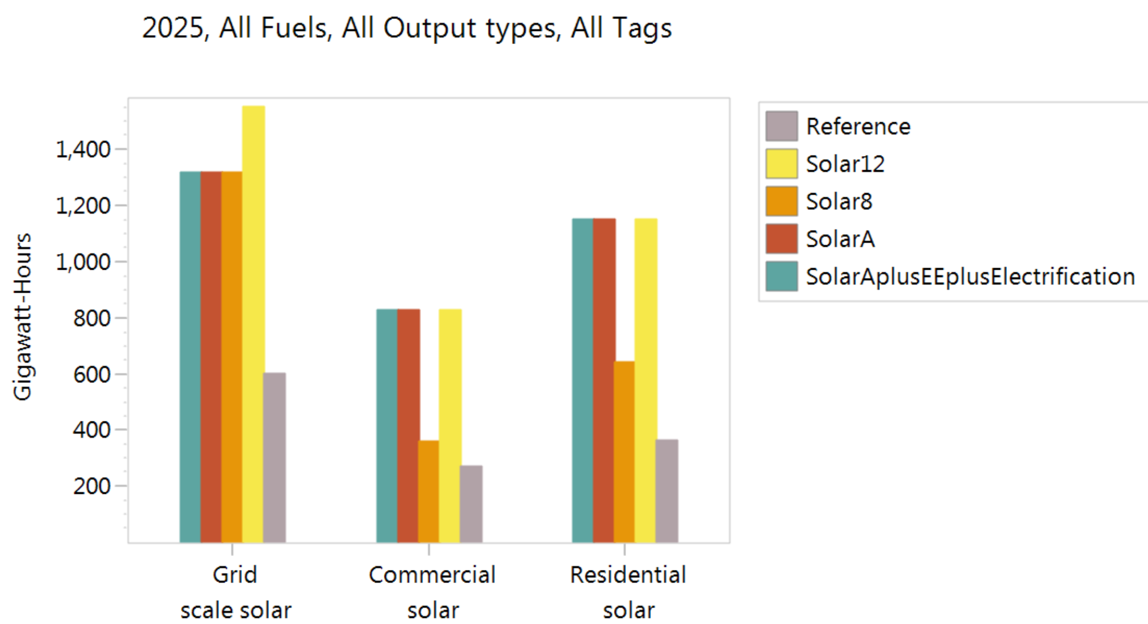


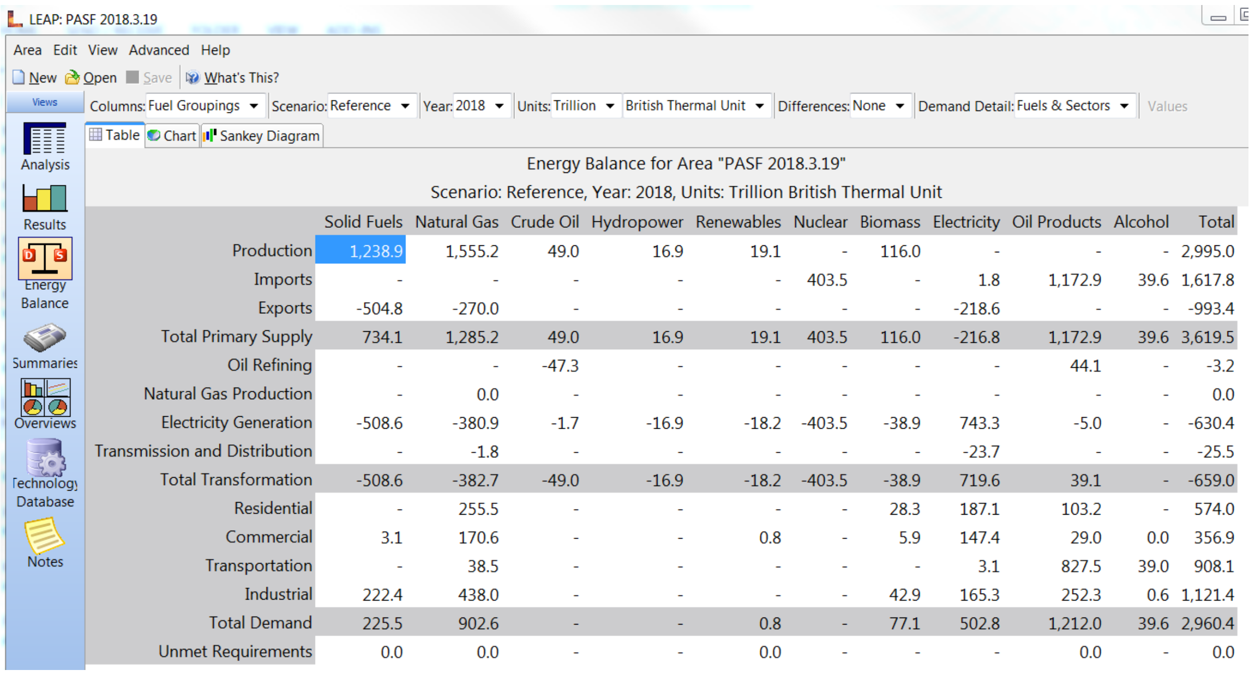
Figure 5: Annual Solar Generation 2025 in Reference and Four Solar Scenarios

After the demand and transformation modules have been specified and developed the LEAP system examines available energy resources (primary: such as anthracite coal, natural gas, and solar and secondary: including products such as gasoline, diesel and heating fuel oil) that are available indigenously both in terms of stocks (for non-renewable) and annual yields (for renewable resources. Import and export availability and or targets can also be specified.

Based on Pennsylvania's history as an electricity exporter, the team modeled electricity generation that meets in state demand of roughly 150 TWh per year, as well as exports of roughly 80 TWh. The finding PA Solar Future Target is based on 10 percent of the instate annual consumption of roughly 150 TWh.

For each year and each scenario LEAP calculates an energy balance which identifies any short falls in supply and resources needed to meet the energy demands. The energy balance and flows in each year are then used to calculate the costs and environmental impacts associated with each scenario.

Figure 6 illustrates a LEAP energy balance table, using 2018 in the reference scenario as an example. All the energy units are presented in Trillion British Thermal Units (TBtu). LEAP permits easy conversion of energy units so that results can be presented in electric equivalent, such as TWh and other physical or energy units.



Energy Balance for Area "PASF 2018.3.19"

Scenario: Reference, Year: 2018, Units: Trillion British Thermal Unit

	Solid Fuels	Natural Gas	Crude Oil	Hydropower	Renewables	Nuclear	Biomass	Electricity	Oil Products	Alcohol	Total
Production	1,238.9	1,555.2	49.0	16.9	19.1	-	116.0	-	-	-	2,995.0
Imports	-	-	-	-	-	403.5	-	1.8	1,172.9	39.6	1,617.8
Exports	-504.8	-270.0	-	-	-	-	-	-218.6	-	-	-993.4
Total Primary Supply	734.1	1,285.2	49.0	16.9	19.1	403.5	116.0	-216.8	1,172.9	39.6	3,619.5
Oil Refining	-	-	-47.3	-	-	-	-	-	44.1	-	-3.2
Natural Gas Production	-	0.0	-	-	-	-	-	-	-	-	0.0
Electricity Generation	-508.6	-380.9	-1.7	-16.9	-18.2	-403.5	-38.9	743.3	-5.0	-	-630.4
Transmission and Distribution	-	-1.8	-	-	-	-	-	-23.7	-	-	-25.5
Total Transformation	-508.6	-382.7	-49.0	-16.9	-18.2	-403.5	-38.9	719.6	39.1	-	-659.0
Residential	-	255.5	-	-	-	-	28.3	187.1	103.2	-	574.0
Commercial	3.1	170.6	-	-	0.8	-	5.9	147.4	29.0	0.0	356.9
Transportation	-	38.5	-	-	-	-	-	3.1	827.5	39.0	908.1
Industrial	222.4	438.0	-	-	-	-	42.9	165.3	252.3	0.6	1,121.4
Total Demand	225.5	902.6	-	-	0.8	-	77.1	502.8	1,212.0	39.6	2,960.4
Unmet Requirements	0.0	0.0	-	-	0.0	-	-	-	0.0	-	0.0

Figure 6: LEAP Energy Balance, Finding Pennsylvania's Solar Future Reference Scenario 2018.

3. LEAP MODELING INPUTS AND DATA SOURCES

The Team collected data from publicly available state level and national sources. The Team used information on sources and assumptions in this report and in stakeholder meeting presentations to summarize the modeling inputs and assumptions, and to convey a general sense of the approach and level of depth and rigor of the modeling.

A) DEMOGRAPHIC AND ECONOMIC ACTIVITY DEMAND DRIVERS

Each sector of the demand tree has a unit that measures activity in the sector. That unit is the "demand driver." LEAP multiplies it by the energy intensity of activities to calculate sector energy demand.

Pennsylvania's population is assumed to grow from 12.8 million in 2015 to 13.2 million in 2020, and 14.1 million in 2030. The number of people per household is assumed to remain constant at 2.29. These assumptions combine to give the number of households, the model's demand driver for residential energy consumption.

The Project Team based the projected change in the energy demand from the industrial sector on the value of products shipped. The Census Bureau provided data from 2014 and 2015, and the Project Team used the national growth rate from the 2017 Annual Energy Outlook to project forward.

Energy consumption in the commercial sector was based on employment in the services-providing sectors. Data from 2014 and projections for 2024 from the Department of Labor were used, with growth beyond 2024 assumed to continue, though at a slower pace.

Transportation energy use was based on the EIA State Energy Data System and the Department of Transportation's Pennsylvania Highway Statistics 2015. There is no demand driver in the transportation sector, total energy by fuel was entered directly in the subsectors: road/rail/air/other.

Table 1: Sources used for Demographic and Economic Demand Drivers

Input and Value	Source	Notes
Population: 2015: 12.8 Million 2030: 14.1 Million	Census Bureau, Center for Rural Pennsylvania	Population serves as a demand driver for residential energy use and transportation.
People Per Household All years: 2.29	Census Bureau, American Community Survey	Residential energy consumption is primarily calculated on a per-home basis.
Commercial Services Employment 2015: 4.9 Million 2030: 5.4 Million	Pennsylvania Department of Labor and Industry	Employment serves as the demand driver for commercial energy use.
Industrial Products Value Shipped 2015: ~$200 billion 2030: ~ $300 billion	Census Bureau, Manufacturers' Shipments, Inventories, & Orders	Industrial energy consumption is primarily driven by this metric.
Electric End Use Efficiency 2% Annual increase in efficiency	Alternative Energy Portfolio Standard (AEPS) targets extended through modeling period, US Energy Information Administration (EIA) Annual Energy Outlook 2017, and professional judgement	All scenarios show some moderate efficiency at the level of the AEPS targets extended through the modeling period. EE scenarios include higher rates of efficiency.
Natural Gas End Use Efficiency .05% Annual increase in efficiency	AEPS targets extended through modeling period, EIA Annual Energy Outlook 2017, and professional judgement	All scenarios show some moderate efficiency at the level of the AEPS targets extended through the modeling period. EE scenarios include higher rates of efficiency.
Industrial End Use Efficiency 1.1% Annual increase in structural efficiency 1% Annual increase in industrial energy efficiency	EIA Annual Energy Outlook 2017, and professional judgement	Includes structural efficiency due to shifts to production of less energy intensive products and improvements in process and end use equipment.

B) FINANCIAL INPUTS

LEAP also uses other basic parameters, including real and nominal discount rates to calculate economic returns.

Long term economic models rely on assumptions about discount rate and inflation to account for the time value of money and future uncertainty.

Real discount rate: 1.75%[120]

- The scenarios consider large scale changes from investments by many different individuals and organizations, and potential public policy.
- While utility investment may be significant, in grid upgrades and potentially owning solar, utilities are not expected to contribute a large share of the scenario investments.
- Therefore utility WACC e.g. may not be the most appropriate estimate of the discount rate.
- As a whole, the scenarios are a societal investment for societal benefits, similar to the Societal Cost Test (SCT), which uses a low discount rate reflecting a higher valuing of future savings.
- The SCT does not have a specific source for a rate, but it is lower than that for the similar Total Resource Cost (TRC) Test, which can use the 10-year Treasury bill rate, which has averaged near 2.25% for the past five years.

Inflation rate: 2.0%

- Target rate for the Federal Reserve. PA's Independent Fiscal Office assumes this rate is achieved in their Economic and Budget Outlook.

C) DEMAND BRANCH INPUTS

Values and inputs used in the LEAP model for the residential branch of the demand tree are documented in Table 2:

Table 2: Residential Energy Demand

Input and Value	Source	Notes
End use saturation	EIA Residential Energy Consumption Survey 2009, Table 8	Cooling is expected in 90% of residential households, 100% for other end uses.
Residential heating end use shares	American Community Survey	In all non-heat pump scenarios, ~50% of residential heating comes from natural gas, ~20% from electric heat, ~15% from oil, and less than 5% each from propane, kerosene, wood, geothermal, and coal.
Residential heating energy intensity	EIA Residential Energy Consumption Survey 2009. Table CE 4.7	Cold climate heat pumps and natural gas boilers are expected to increase in efficiency over time. Other residential heating devices remain constant in energy consumption per house.

[120] Regulatory Assistance Project & Synapse, *Energy Efficiency Cost-Effectiveness Screening*, http://www.synapse-energy.com/sites/default/files/SynapseReport.2012-11.RAP_.EE-Cost-Effectiveness-Screening.12-014.pdf

Input and Value	Source	Notes
Residential cooling end use shares	EIA Residential Energy Consumption Survey 2009, Table HC 8	
Residential cooling energy intensity	EIA Residential Energy Consumption Survey 2009, Table HC 8	Cooling is expected to increase slightly in efficiency over time.
Residential water heating end use shares	EIA Residential Energy Consumption Survey 2009, Table HC8.8	Share of water heating provided by natural gas, propane, electricity, and oil are steady over the modeling period.
Residential water heating energy intensity	EIA Residential Energy Consumption Survey 2009, Table CE 4.7	Electric and natural gas water heaters are expected to slightly improve in efficiency over the modeling period
Residential appliance end use shares	EIA Residential Energy Consumption Survey 2009, Table CE 4.7	
Residential appliance energy intensity	EIA Residential Energy Consumption Survey 2009	
Residential lighting and plug loads end use shares	EIA Residential Energy Consumption Survey 2009	Full saturation for both categories for duration of the model.
Residential lighting and plug loads energy intensity	EIA Residential Energy Consumption Survey 2009	Average lighting and plug load efficiency is expected to increase throughout the model period as the transition to LED lighting and more efficient devices continues.

The commercial, industrial, and transportation sector demand trees were modeled based upon total fuel use and economic drivers. The team did not conduct an end use level of analysis at the same level of detail as was conducted for the residential sector (space conditioning → heating → device → intensity). The diversity of end uses and devices in the commercial and particularly the industrial sector mean that such a detailed analysis would be time consuming and was not deemed to add sufficient value for the objectives of this study. The LEAP model allows users to vary the level of detail by each of the model segments and still conduct an integrated analysis of the total energy economy which is very helpful and adaptable based on the research objectives. Table 3 summarizes the commercial and industrial branch inputs and sources.

Table 3: Commercial, Industrial, and Transportation Energy Demands

Input and Value	Source	Notes
Commercial total use by fuel	EIA State Energy Data System	Employment in services is demand driver for future years. Also impacted by efficiency factors.
Industrial total use by Fuel	EIA State Energy Data System	
Transportation total use by mode, and fuel	EIA State Energy Data System, PA Highway Statistics, EIA's Annual Energy Outlook for 2017, Electric Vehicle Industry Expertise	

D) PV COSTS AND PERFORMANCE

Current solar costs are based on Pennsylvania data in the National Renewable Energy Laboratory's OpenPV data set[121], and cost projections are sourced from the national averages projections in the National Renewable Energy Lab's 2017 Annual Technology Baseline (ATB). The Open PV data contains cost information from more than 1 million solar installations representing more than 16 GW of installed capacity.

Current Pennsylvania solar costs are above national averages in Open PV as a result of Pennsylvania having a less developed market and policies that have yet to build the market for solar seen in other parts of the nation. The discrepancy is largest for commercial solar projects, followed by residential and utility scale, respectively.

Figure 7 illustrates the costs for systems by class in Pennsylvania in the darker colors and national average in the same color with a lighter shade. As the market in Pennsylvania grows to meet the Finding PA Solar future target, the gaps in installed costs are projected to diminish and disappear by 2030.

121 https://openpv.nrel.gov/

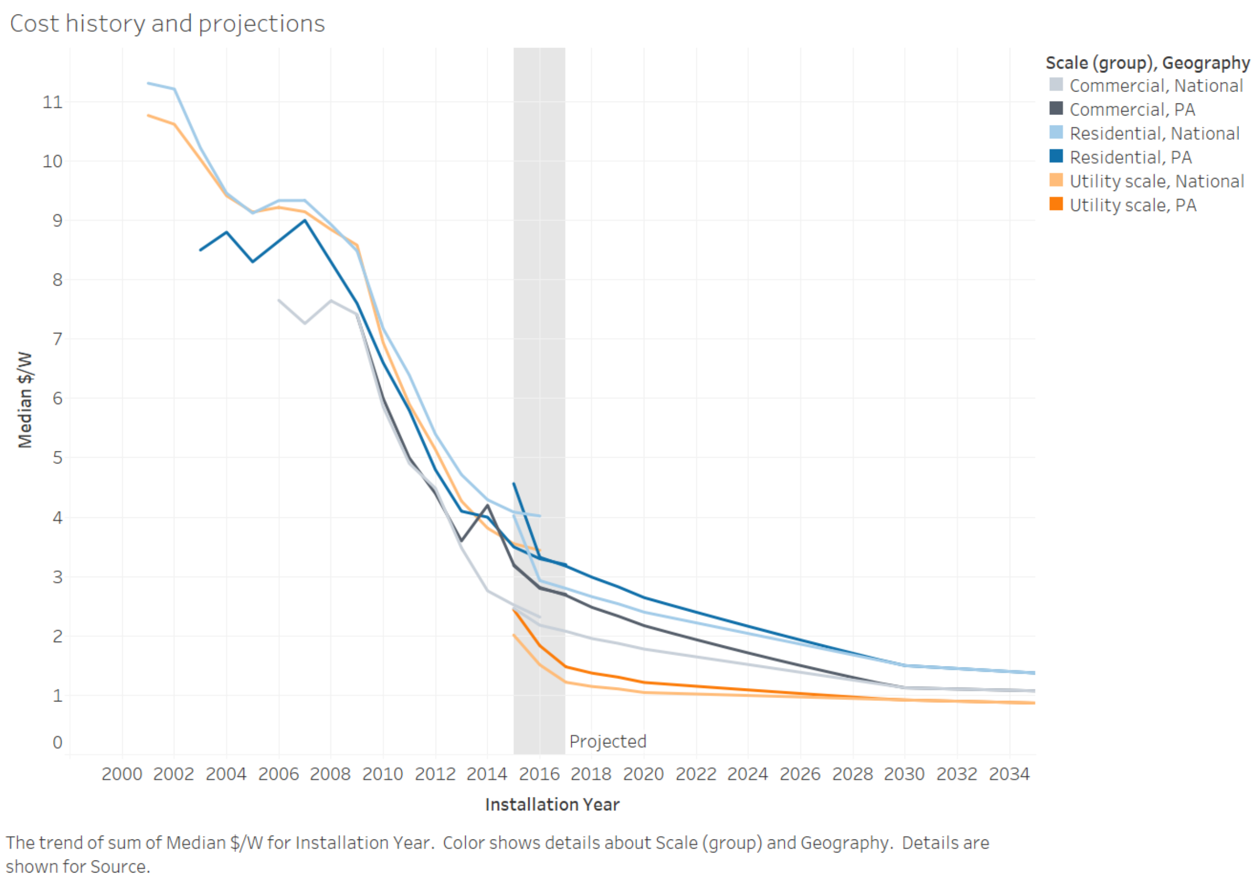


Figure 7: Historic and Projected PV costs (Open PV and NREL Technology Database)

The starting and projected 2030 costs and performance for three system types are based on the Open PV data and the cost projections in the Technology Database are summarized in Table 4.

Table 4. PV Cost and Performance Inputs

	Residential	Commercial	Grid scale
Capacity factor (DC / AC, %)	14%	12%	16%
(kWh / kW / year)	1,205	1,091	1,433
Capital cost ($ / kW)			
2018 w/o incentive	2,989	2,481	1,373
2018 w / ITC, tariff	2,281	1,931	1,125
2030 (ITC gone)	1,547	1,171	958
O&M 2018 ($ / kW·year)	20	15	12

E) GRID INTEGRATION COSTS

Reaching the 10% solar target can have additional costs related to the integration of solar as an intermittent and distributed resource on the grid. During the September 2017 meeting in Villanova, stakeholders heard a presentation from PJM on integration potential for the bulk power system. The presentation referenced earlier research commissioned by PJM to look at the impact to grid operations from integration of higher levels of renewables into the PJM interconnection system.[122] Key findings included that integration of up to 30% energy from wind and solar would not cause significant reliability issues. At a more granular level, estimates that up to 11 GW of solar in Pennsylvania could be handled without causing significant issues. This value is similar to the what the PA Solar Future Team has calculated to be the required new solar capacity in PA to meet the 10% by 2030 target.

On the distribution side of the utility system, the team included estimated upgrade costs based on a meta-study of integration cost studies.[123] Figure 8 and Table 5 are drawn directly from the Synapse report, illustrate that the value of $5/MWh for solar integration costs on the distribution system are relatively conservative. This is particularly true if steps or strategies are developed to locate solar on distribution feeders where there is available hosting capacity, or where costs for increased hosting capacity are relatively low.

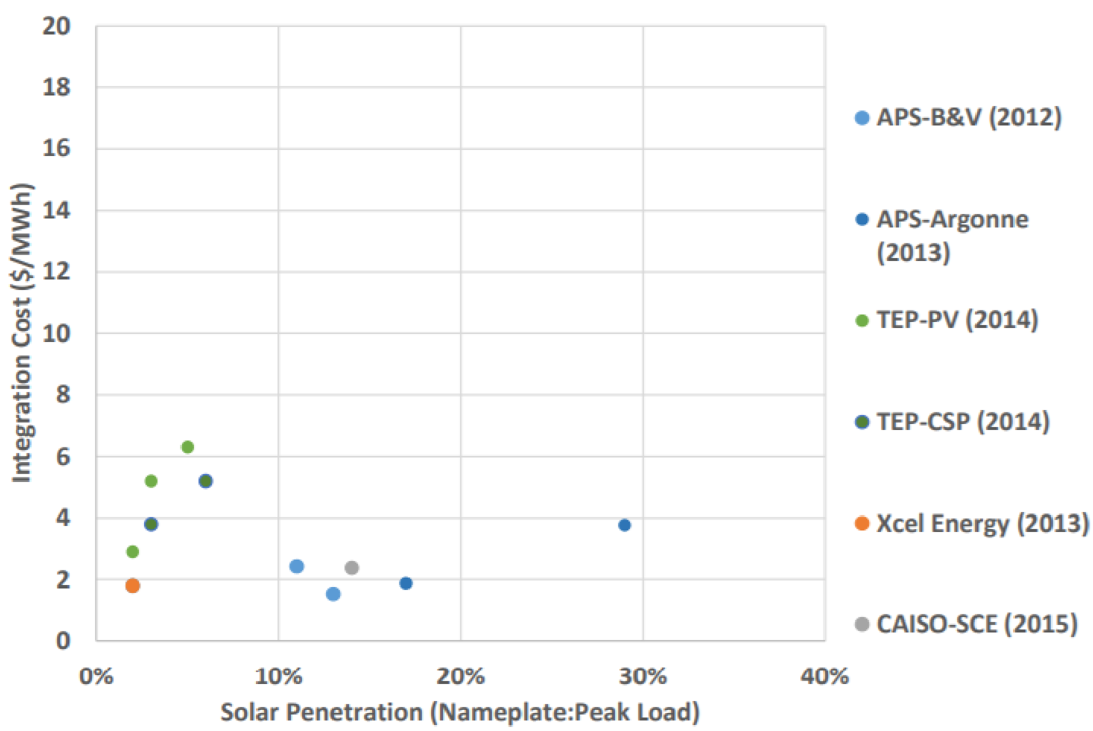


Figure 8: Solar integration costs by level of penetration (From Synapse report).

122 http://www.pjm.com/committees-and-groups/subcommittees/irs/pris.aspx

123 Synapse, 2015, "A Solved Problem: Existing measures provide low-cost wind and solar integration," http://www.synapse-energy.com/sites/default/files/A-Solved-Problem-15-088.pdf

Table 5: Source Studies cited by Synapse Report

Study	Study Period	System Peak (MW)	Type of Solar	Penetration on Peak Demand Basis (%)	Integration Cost ($/MWh)
B&V - APS 2012[a]	2020	8,200	PV	13%	$1.53
	2030	10,900	PV	11%	$2.43
Argonne – APS 2013[b*]	2027	10,090	PV	17%	$1.88
	2027	10,090	PV	29%	$3.77
TEP IRP 2014[c]	2014-2028	3,198	PV	2%	$2.90
	2014-2028	3,198	PV	3%	$5.20
	2014-2028	3,198	PV	5%	$6.30
	2014-2028	3,198	CSP	3%	$3.80
	2014-2028	3,198	CSP	6%	$5.20
Xcel Energy 2013[d]	2012-2034	8,000	DG PV	2%	$1.80
CAISO-SCE 2015[e†]	2024	51,000	PV	14%	$2.38

See report for citations for each of the studies in Table 5.

F) COSTS FOR FUELS DISPLACED BY SOLAR

Computing the economic results of the solar and alternative scenarios requires the team to have forecasts of the future fuel prices for the fuels that are displaced as solar generation grows. The team used the Energy Information Administration's Annual Energy Outlook as our source for future fuel costs.

Figure 9 illustrates the EIA's Annual Energy Outlook forecasts relatively level fuel prices throughout the analysis period.

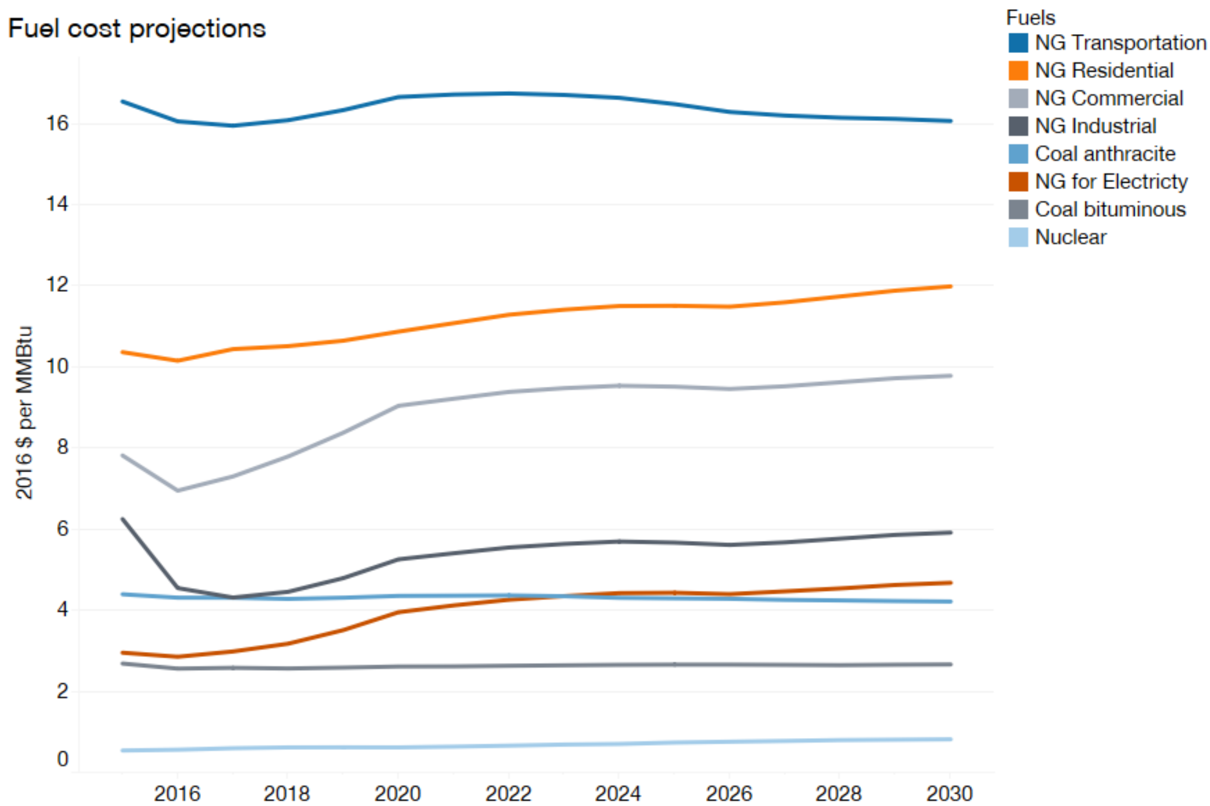


Figure 9: Data from EIA's Annual Energy Outlook (AEO) 2017, Reference scenario, Mid-Atlantic.

The savings in the economic modeling come from reduced purchase of these fuels, as well as a reduction in variable O&M costs, by plant type. The later data are drawn The National Renewable Laboratory's Annual Technology Baseline.[124]

G) EXTERNALITY COSTS

Externalities include the environmental impacts of emissions from fossil fuels. The economic value of environmental externalities can be estimated using two approaches: according to their impact on society, or according to their compliance cost.

Table 6 gives the damage or impact based costs, and recent compliance based costs used to calculate the scenario costs including externalities.

124 https://atb.nrel.gov/

Damage costs are from a study that used "a high-resolution model to simulate and compare the monetized public health and climate benefits of four different illustrative EE/RE installation types in six different locations within the Mid-Atlantic and Lower Great Lakes of the United States." [125]

Compliance costs are based on 2017 auction results from the relevant markets:

- The carbon dioxide price is from the Regional Greenhouse Gas Initiative (RGGI).[126]
- The nitrogen oxides price is a rough estimate based on recent seasonal and annual prices in the monthly spot market.[127]
- The sulfur dioxides price is the weighted average of the 2017 spot auction and the advanced auction, for allowances first usable in 2017 and 2024 respectively.[128]

Table 6. Externality costs based on: estimated impact to society and estimated cost to mitigate.

Pollutant	Damage Cost	Compliance Cost	Cost Units
Carbon Dioxide	47	4	USD/metric tonne
Nitrogen Oxides	10	0.20	USD/kilogram
Sulfur Dioxides	20	0.035	USD/kilogram

4. LEAP MODELING RESULTS

A) PRIMARY AND FINAL ENERGY DEMAND

When considering the total energy system, it is important to understand the difference between primary and final energy demands. Primary energy demand is the total amount of resources consumed. It includes energy that provides end use services as well as energy used to source and move that energy: energy lost at power plants, and energy lost from power lines in transmission and distribution. Primary and final energy vary based on many factors including the type of fuel used, the type of power plant, and proximity to end users. Final energy consumption refers only to energy directly consumed by end users. In this report, final energy is used unless otherwise noted.

	Primary Energy Demand (TBtu)	Final Energy Demand (TBtu)
2015	3,420	2,930
2020	3,450	2,974
2025	3,443	2,973
2030	3,384	2,922

Table 7. Primary and final energy demand (Solar A scenario).

125 Buonocore et al., "Health and climate benefits of different energy-efficiency and renewable energy choices," (Nature 2015, doi:10.1038/nclimate2771), Fig 4.
126 RGGI, "Allowance Prices and Volumes," https://rggi.org/auctions/auction-results/prices-volumes.
127 Monitoring Analytics LLC, "Quarterly State of the Market Report for PJM: January through March 2017," http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2017/2017q1-som-pjm-sec8.pdf.
128 EPA, 2017 SO2 Allowance Auction, https://www.epa.gov/airmarkets/2017-so2-allowance-auction-0.

B) FINAL DEMAND BY SECTOR

As noted above, energy demand does not vary across the three primary scenarios. It does vary slightly over time. shows final energy consumption by year and sector. Population growth and increasing industrial production is offset by an increase in transportation efficiency, making energy demand nearly flat from 2015 to 2030.

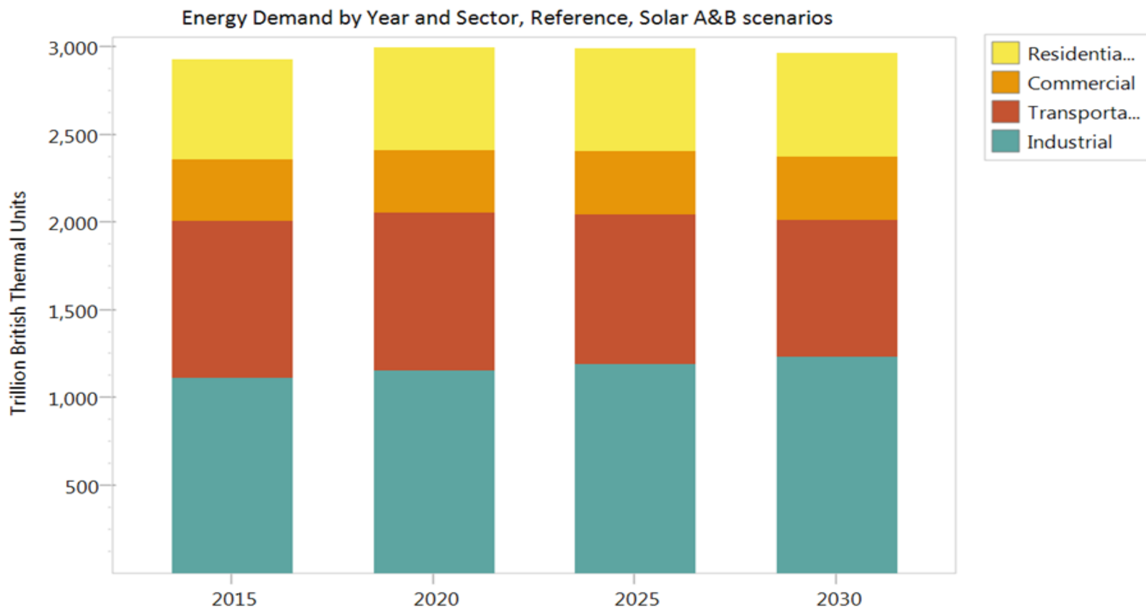


Figure 10. Energy Demand by Year and Sector

C) ADDITIONAL SCENARIOS COMPARISONS

The team developed additional scenarios which built upon the Solar A and Solar B scenarios to incorporate stakeholder feedback and illustrate tradeoffs between potential future paths. Stakeholders requested scenarios with increased efficiency, electrification, and wind. The team took the following modifications and combined them in a variety of scenarios listed below.

Extra Efficiency, "EE": Energy electric efficiency grows at 2% annually and gas efficiency grows at 0.5% annually, instead of 0.8% and 0.1% as described in the original scenarios. Leading states achieve 3% savings from energy efficiency programs annually[129]. Six states currently have annual energy efficiency targets of 2% or greater[130], and this is not considered out of reach for Pennsylvania.

"Electrification": A combination of changes in heat pumps and electric vehicles. Air and ground source heat pumps provide 18% of household heat by 2030. This change displaces heat currently provided by oil, propane, kerosene, and electric resistance. Additionally, this scenario includes significant increases in

[129] http://aceee.org/sites/default/files/publications/researchreports/u1710.pdf
[130] https://aceee.org/sites/default/files/state-eers-0117.pdf

electric vehicles from 3,600 in 2017 to 600,000 in 2030. For context, there were over 8,000,000 passenger vehicles in PA in 2016.[131]

"Wind": The "Wind" scenario grows wind to provide 10% of in-state electricity, like the solar goal. This requires 5.2 GW in 2030, as compared to 1.8 GW in 2030 in all other scenarios. Two checks show this is a reasonable number. One is that 5.2 GW can be reached with a 10% compound annual growth rate, which is achievable. The second was a comparison to NREL's Eastern Wind Dataset.[132] That study Focuses on integrating high levels of wind generation and includes 7 GW of viable sites in PA.

Figure 11 illustrates changes in final energy demand for the additional scenarios in comparison to the reference.

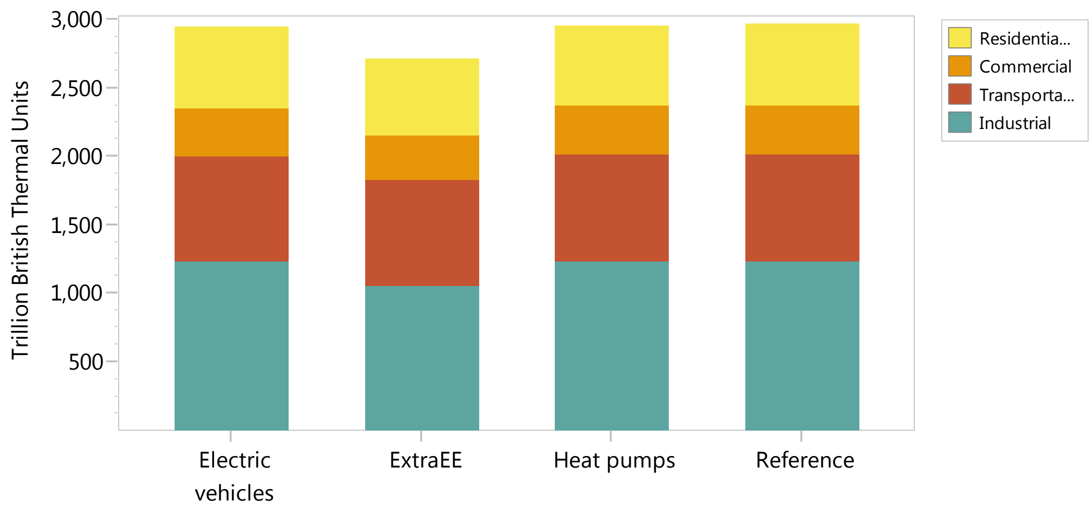


Figure 11. Changes in demand by scenario.

131 PA DOT, "Report of Registrations," http://www.dot.state.pa.us/public/dvspubsforms/BMV/Registration%20Reports/ReportofRegistration2016.pdf.

132 NREL, "Eastern Wind Dataset," https://www.nrel.gov/grid/eastern-wind-data.html.

Table 8 compares the additional scenarios developed by the team across several key indicators.

Table 8: Alternative Scenarios in the PA Solar Future Study

	Scenario	2030 Total Primary Energy Consumption (TBTUs)	2030 Final Electrical Energy Consumption (TBTUs)	Solar as % of retail power	Wind as % of retail power	Total Renewables as % of power
Reference	No Modification	3,440	514	1%	4%	12%
	EE	3,110	441	1%	5%	14%
	Wind	3,415	514	1%	11%	19%
	Heat Pumps	4,451	535	1%	4%	11%
	Electric Vehicles	3,428	519	1%	4%	12%
SolarA	No Modification	3,410	514	10%	4%	20%
	EE	3,083	441	11%	5%	23%
	EE, Electrification	3,076	465	11%	4%	22%
	EE, Electrification, Wind	3,052	465	11%	12%	30%
	Solar 8%	3,417	514	8%	4%	18%
	Solar 12%	3,410	514	12%	4%	23%
SolarB	No Modification	3,408	514	10%	4%	21%
	EE	3,082	441	12%	5%	24%
	EE, Electrification	3,074	465	11%	4%	23%

D) ECONOMIC RESULTS FOR ADDITIONAL SCENARIOS

The economic results for the additional scenarios are summarized in Tables 9,10, and 11. Table 9 compares Solar A and its modifications to the Reference case. Note that Solar A plus EE has lower net costs and also reduces total emissions significantly more than the Solar A without additional efficiency.

Table 9: Solar A and variations economic results compared to reference

Cumulative Costs && Benefits: 2015-2030. Relative to Scenario: Reference. Discounted at 1.8% to year 2017. Units: Billion 2017 U.S. Dollar	SolarA	SolarA plusEE	Solar A Plus EE Plus Elec	Solar A Plus EE Plus Elec Plus Wind
Demand	-	0.9	5.5	5.5
Residential	-	0.5	3.7	3.7
Commercial	-	0.2	0.2	0.2
Transportation	-	-	1.4	1.4
Industrial	-	0.1	0.1	0.1
Transformation	10.1	10.0	10.1	15.4
Transmission and Distribution	0.1	0.1	0.1	0.2
Electricity Generation	10.0	9.9	10.0	15.2
Natural Gas Production	-	-	-	-
Oil Refining	-	-	-	-
Resources	-0.3	-2.8	-2.6	-3.0
Production	-0.3	-2.7	-2.3	-2.7
Imports	-0.0	-0.1	-0.3	-0.3
Exports	-	-	-	-
Unmet Requirements	-	-	-	-
Environmental Externalities	-	-	-	-
Non Energy Sector Costs	-	-	-	-
Net Present Value	9.8	8.0	13.0	17.9
GHG Savings (Mill Tonnes CO2e)	317.8	2,270.5	2,265.9	2,574.0
Cost of Avoiding GHGs (U.S. Dollar/	30.9	3.5	5.7	7.0

Table 10 compares the economic results for Solar B and its modifications. The same pattern as illustrated for Solar A emerges, with the extra EE reducing net costs and increasing emissions reductions significantly.

Table 10: Solar B and variations economic results compared to reference

Cumulative Costs && Benefits: 2015-2030. Relative to Scenario: Reference. Discounted at 1.8% to year 2017. Units: Billion 2017 U.S. Dollar	SolarB	Solar B Plus EE	Solar B Plus EE Plus Elec
Demand	-	0.9	5.5
Residential	-	0.5	3.7
Commercial	-	0.2	0.2
Transportation	-	-	1.4
Industrial	-	0.1	0.1
Transformation	8.6	8.5	8.5
Transmission and Distribution	0.1	0.1	0.1
Electricity Generation	8.5	8.4	8.4
Natural Gas Production	-	-	-
Oil Refining	-	-	-
Resources	-0.3	-2.8	-2.6
Production	-0.3	-2.7	-2.2
Imports	-0.0	-0.1	-0.3
Exports	-	-	-
Unmet Requirements	-	-	-
Environmental Externalities	-	-	-
Non Energy Sector Costs	-	-	-
Net Present Value	8.3	6.5	11.4
GHG Savings (Mill Tonnes CO2e)	314.3	2,266.8	2,262.3
Cost of Avoiding GHGs (U.S. Dollar/Tonne CO2e)	26.4	2.9	5.0

Finally, Table 11 compares the Solar 8 and Solar 12 to the Reference scenario. They have relatively lower and higher net costs than the Solar A and B scenarios which attain the ten percent target.

Table 11: Solar 8 and Solar 12 economic results compared to reference

Cumulative Costs && Benefits: 2015-2030. Relative to Scenario: Reference. Discounted at 1.8% to year 2017. Units: Billion 2017 U.S. Dollar	Solar8	Solar12
Demand	-	-
Residential	-	-
Commercial	-	-
Transportation	-	-
Industrial	-	-
Transformation	6.3	12.4
Transmission and Distribution	0.1	0.1
Electricity Generation	6.2	12.3
Natural Gas Production	-	-
Oil Refining	-	-
Resources	-0.2	-0.4
Production	-0.2	-0.4
Imports	-0.0	-0.0
Exports	-	-
Unmet Requirements	-	-
Environmental Externalities	-	-
Non Energy Sector Costs	-	-
Net Present Value	6.1	12.0
GHG Savings (Mill Tonnes CO2e)	225.5	407.5
Cost of Avoiding GHGs (U.S. Dollar/Tonne CO2e)	27.0	29.5

5. FINANCIAL MODELING RESULTS

The System Advisor Model (SAM) is a software tool developed by the National Renewable Energy Laboratory to model the performance of energy systems on an hour-by-hour basis and to develop energy performance into a cash flow analysis.

For solar projects serving residential and commercial customers, as well as grid scale projects selling power through power purchase agreements, SAM accounts for solar system design, hourly weather (including cloud cover), and hourly solar insolation. By combining energy and financial performance, SAM allows users to compare systems based on a range of revenues, costs, tax credits, incentives, and financing options.

The Team prepared project scenarios serving residential and commercial customers in a number of different locations. For example, the residential system modeled for Philadelphia estimates energy production for 7.5 kW open-rack system installed on a south-facing roof with a 20 degree pitch. SAM accounts for system inefficiencies and panel degradation over time, as well as escalating costs and the value of avoided electricity purchases. In addition to the Philadelphia residential system, the Team also modeled a 200 kW commercial rooftop system in Pittsburgh and a 20 MW grid scale

SAM is capable of conducting a parameter analysis that calculates a project's financial value given a range of possible inputs. While precise future costs are unpredictable, the Team analyzed solar project profitability at a range of module costs and incentive levels. SAM uses the term Production Based Incentive, or PBI, for incentives that are based on actual electricity generation. (By contrast, other incentives may be based on the generating capacity of the system, such as tax credits or accelerated depreciation.) The value of SRECs are treated as production based incentives because they are linked to each MWh that is generated.

An analysis found that customer financial return, as measured by payback period and levelized cost of energy (LCOE), are favorable in nearly all scenarios. In Philadelphia's residential scenario, for example, even when accounting for higher module costs or lower SREC prices, payback periods generally ranged between 8 and 13 years. The grid scale scenario is evaluated using LCOE rather than payback period because LCOE is more easily compared to other energy resources. Nominal LCOE generally ranged between 5 and 9 cents per kilowatt-hour, which is generally comparable with the cost of other new resources.

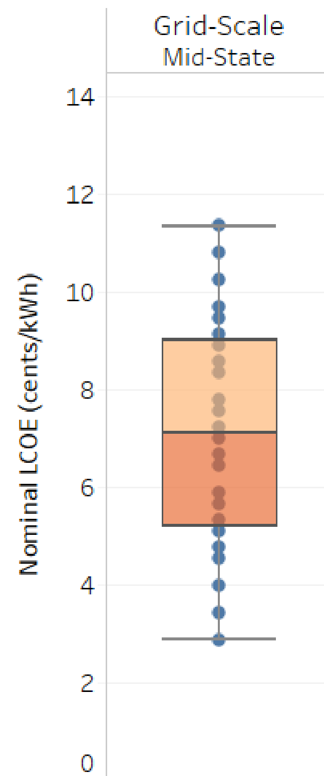
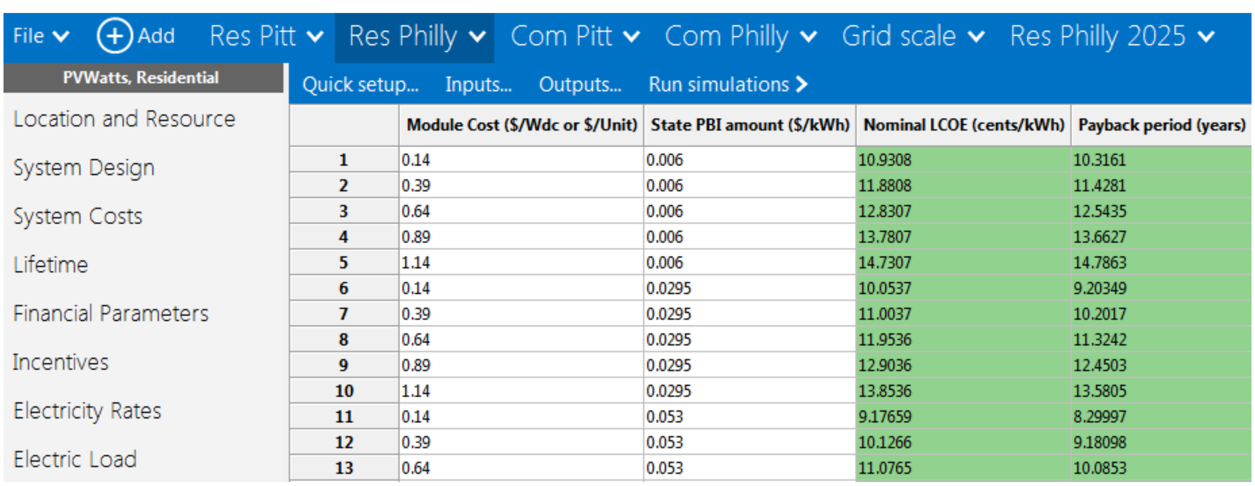


Figure 12: Nominal levelized cost of energy (LCOE) for grid scale solar system mid - state 2025 with varying PV module and SREC prices. This box plot chart identifies the middle 50% of outcomes in orange. Each point represents one outcome as measured by LCOE; lower costs are more desirable.



	Module Cost ($/Wdc or $/Unit)	State PBI amount ($/kWh)	Nominal LCOE (cents/kWh)	Payback period (years)
1	0.14	0.006	10.9308	10.3161
2	0.39	0.006	11.8808	11.4281
3	0.64	0.006	12.8307	12.5435
4	0.89	0.006	13.7807	13.6627
5	1.14	0.006	14.7307	14.7863
6	0.14	0.0295	10.0537	9.20349
7	0.39	0.0295	11.0037	10.2017
8	0.64	0.0295	11.9536	11.3242
9	0.89	0.0295	12.9036	12.4503
10	1.14	0.0295	13.8536	13.5805
11	0.14	0.053	9.17659	8.29997
12	0.39	0.053	10.1266	9.18098
13	0.64	0.053	11.0765	10.0853

Figure 13: Screenshot of parametric analysis in SAM tool

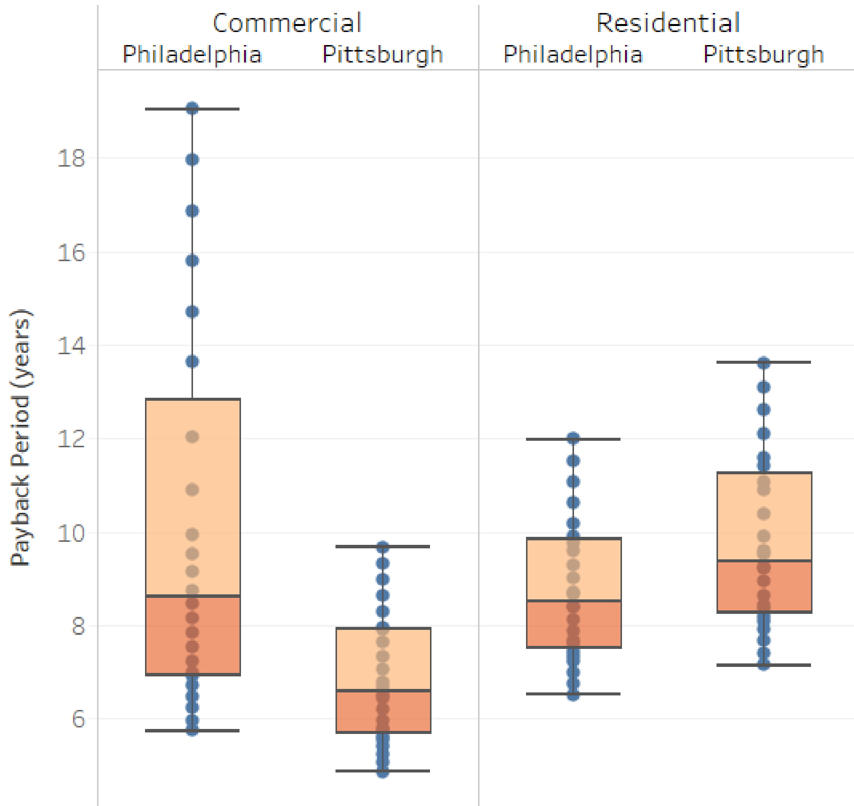


Figure 14: Simple payback in years for residential and commercial solar systems with varying PV module and SREC prices. This box plot chart identifies the middle 50% of outcomes in orange. Each point represents one outcome as measured by payback period; shorter payback periods are more desirable. The residential examples are based on 2020 projected costs, the commercial are for 2030.

6. JOBS AND ECONOMIC DEVELOPMENT IMPACT MODEL

The Jobs and Economic Development Impacts (JEDI) uses an Excel-based model to estimate the impact of energy infrastructure development at the state level. The models account for three elements related to a project, such as a new power plant: (1) on-site labor and project development impacts; (2) local revenue (including tax revenue) and supply chain impacts; and, (3) induced impacts on jobs and the economy. The tool was developed by the National Renewable Energy Laboratory.

The Solar A and Solar B scenarios described in the report were modeled using JEDI. The models used costs taken from NREL's SAM tool (version 2017.9.5) and scaled such that totals matched the PA scenarios described in NREL's Annual Technology Baseline. Balance of system costs (excluding modules and inverters) were split between mounting costs at 75% and electrical costs at 25%.

Table 10 and 11 in the report are based on assumptions that 50% of the installation labor force is based outside Pennsylvania. Table 12 below illustrates inputs if 90% of installation labor is Pennsylvania-based, as might be expected as solar installations grow and the solar workforce matures. Table 13 compares the job impacts of the 50% and 90% in state labor models.

Table 12: JEDI 90% In-State Labor Inputs

Installation Costs	Purchased	Manufactured
Materials & Equipment	Locally (%)	Locally (Y or N)
Mounting (rails, clamps, fittings, etc.)	60%	N
Modules	30%	N
Electrical (wire, connectors, breakers, etc.)	95%	N
Inverter	30%	N
Labor		
Installation	90%	
Other Costs		
Permitting	100%	
Other Costs	100%	
Business Overhead	100%	
Sales Tax (Materials & Equipment Purchases)	100%	
PV System Annual Operating and Maintenance Costs		
	Local	
Labor	Share (%)	
Technicians	90%	
	Purchased	Manufactured
Materials and Services	Locally (%)	Locally (Y or N)
Materials & Equipment	50%	N
Services	100%	

Table 13: Estimated gross new jobs, by scenario and local labor rate

	50% In-State Labor		90% In-State Labor	
Scenario	**Solar A**	**Solar B**	**Solar A**	**Solar B**
Construction period Jobs	100,604	67,716	116,382	81,141
Ongoing Jobs	1,086	983	1,775	1,619

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