ENVISIONING PENNSYLVANIA'S ENERGY FUTURE

Powering the Commonwealth's Energy Needs with 100 Percent Renewables by 2050

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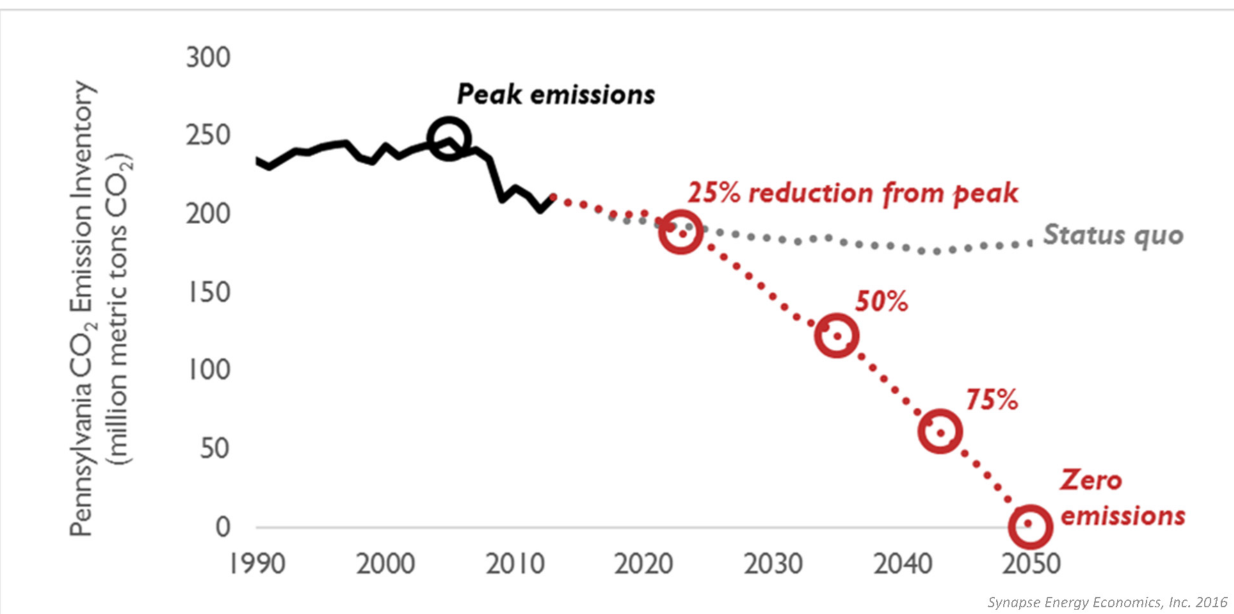
Serious, imminent, and irreversible damages to natural ecosystems, infrastructure, agricultural production, and human health make dramatic reduction of greenhouse gas emissions a key priority for communities around the world. Most greenhouse gases are emitted as a result of our use of energy, and the Commonwealth of Pennsylvania is no exception in this regard.

Delaware Riverkeeper Network asked Synapse Energy Economics and EQ Research to find a path forward that will enable Pennsylvania to serve its energy needs entirely with clean, zero-emission renewables by 2050. Summary Figure 1 shows the results of our planning effort based on detailed electric system modeling and current knowledge of emerging energy technologies: On its current track, Pennsylvania's energy-related carbon dioxide (CO_2) emissions fall only gradually over the next decades.

In our "PA-100%RE" scenario, emissions from energy consumption reach 50 percent of their peak levels by 2035 and zero metric tons of CO_2 by 2050. Without these emission-reduction measures in the status quo "Reference" case, emissions continue to fall but much more slowly; in 2050, in the Reference scenario, Pennsylvania emits 182 million metric tons of CO_2 into the atmosphere. This is only 19 million tons less than recent historical levels, and is insufficient to avoid catastrophic climate change.



Summary Figure 1. Pennsylvania's path forward to zero emissions

Measuring Emissions

Our study analyzed Pennsylvania's CO_2 emissions from energy consumption. Because of this focus, it is important to make clear what is and is not included in our inventory of Pennsylvania's emissions, past and future.

- **Energy-related emissions are included in this analysis.** These encompass both emissions from electricity generation and those from direct use of fossil fuels, such as burning natural gas in homes and businesses for heat and hot water.
- **Within energy-related emissions, we focus on emissions from energy consumption.** We only include emissions associated with energy consumed by Pennsylvania consumers or with end uses attributed to Pennsylvania in this inventory.
- **CO_2 emissions from fossil fuel combusted to serve Pennsylvania's energy needs are included, regardless of where they occur.** This includes emissions from out-of-state electric generators that provide electricity imports to Pennsylvania. Similarly, this inventory gives Pennsylvania credit for out-of-state renewables in which it invests by purchasing their "renewable energy certificates."
- **Non-energy-related emissions are not a part of this analysis.** Emissions that are produced as by-products of industrial processes, or that result from agriculture or land-use changes, are not included in an inventory of the impacts of energy consumption.
- **Energy produced but not consumed in Pennsylvania is not included.** We assume that emissions associated with electricity exports are accounted for in the emissions inventories of the states in which that electricity is consumed.
- **CO_2 and non-CO_2 greenhouse gases from upstream extraction and refining are not included.** Other exclusions from this inventory include methane emissions from natural gas fracking or pipeline leaks, as well as emissions that result from the production of solar panels and wind turbines. CO_2 emissions from biomass and non-CO_2 greenhouse gas emissions resulting from fossil fuel are also omitted from this analysis.

Non-energy-related emissions, emissions from energy production, and non-CO_2 or upstream greenhouse gases are all critical to effecting a comprehensive strategy to avoid dangerous climate change. Our scenario of serving 100 percent of Pennsylvania's energy consumption with renewables by 2050 is just one important input into an all-inclusive energy plan for the Commonwealth.

IN	OUT
CO_2 emissions	Non-CO_2 greenhouse gases
from	and
Fossil fuel combustion	"Upstream" emissions
underlying	and
Energy	Non-energy emissions
created for	and
Consumption in Pennsylvania	Production in Pennsylvania

Building a Green Future

1. Using electricity more efficiently

Energy efficiency reigns as by far the most cost-effective way of avoiding CO_2 emissions in the electric sector today. By bolstering existing energy efficiency programs to match those currently implemented in the most energy-efficient states, Pennsylvania reduces its electric sales serving existing end uses by 23.5 percent by 2050 in the PA-100%RE scenario, compared to a 9.3 percent reduction from efficiency in the Reference scenario.

2. Electrifying Pennsylvania

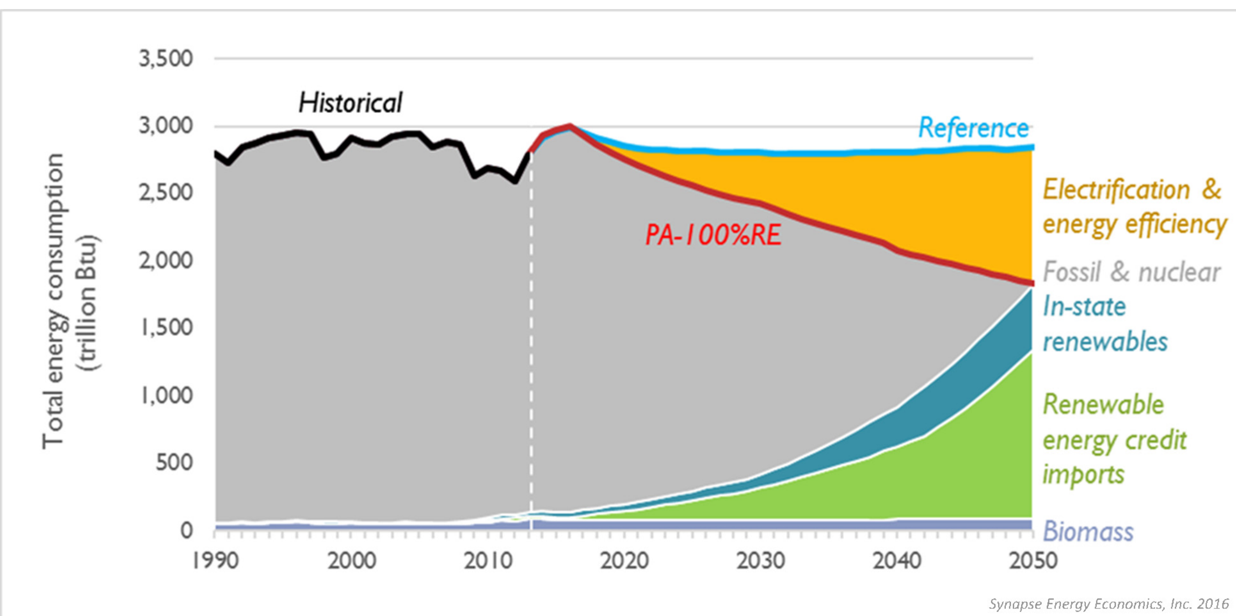
A second key step in achieving zero emissions in Pennsylvania by 2050 is the electrification of energy uses that currently consume fossil fuels at the point-of-use. These include burning gasoline in cars, using natural gas to heat homes, and the consumption of coal for industrial processes. Electrifying these end uses triples electric sales in Pennsylvania by 2050, compared to a Reference case.

3. Building renewable energy resources in the Commonwealth

To meet this new higher demand for electricity in the PA-100%RE scenario, 81 GW of renewables is built in Pennsylvania by 2050. Nearly 90 percent of this renewable capacity comes from solar panels on rooftops and small solar "farms," and nearly half of this incremental renewable capacity is built between 2040 and 2050.

4. Laying claim to renewables outside of Pennsylvania

Pennsylvania's current renewable portfolio standard allows the state to claim renewables for which its electric utilities purchase renewable energy certificates (RECs) anywhere in the mid-Atlantic region. In addition to building new renewable electric generators in state, we match Pennsylvania's energy consumption—in both the PA-100%RE scenario and the Reference case—with renewable electric generation for which the state purchases RECs. Both in- and out-of-state renewables get counted as part of Pennsylvania's generation, and they cannot be used to comply with any other states' renewable portfolio standards. By 2050, Pennsylvania's demand for renewable generation—and these states' own smaller renewable demand—results in 138 GW of additional wind and solar in states surrounding Pennsylvania (see Summary Figure 2).

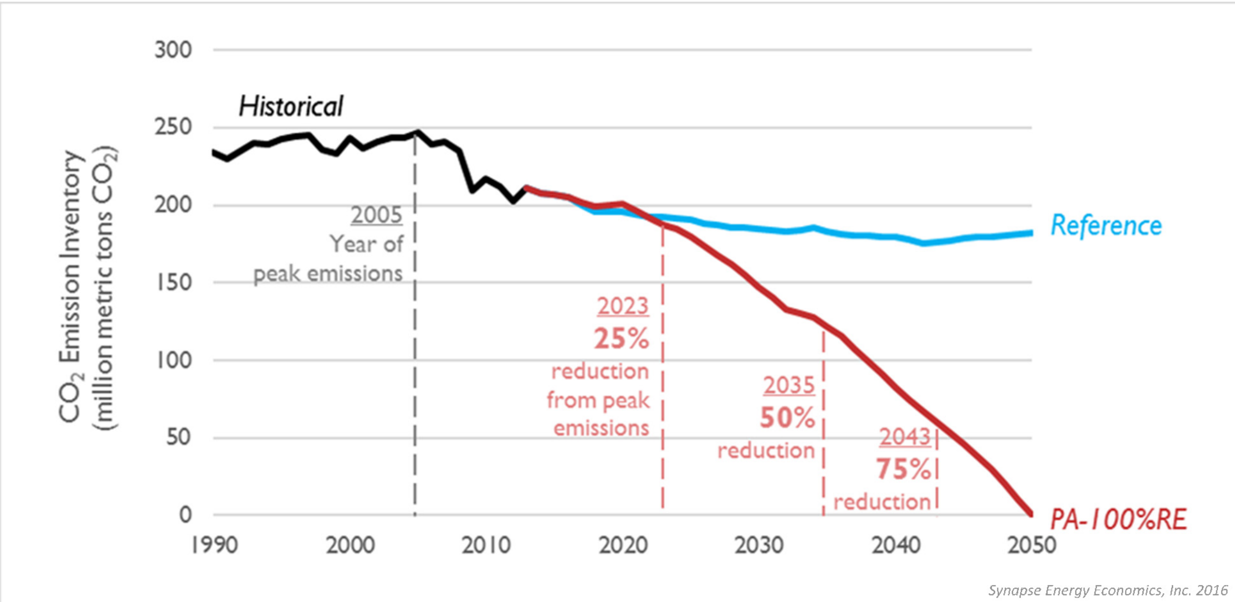


Summary Figure 2. Total energy consumption in Pennsylvania in the PA-100%RE scenario

100 Percent Renewables, Zero Emissions

Through the use of energy efficiency, electrification of all energy uses, and demand for both in-state and out-of-state renewables, Pennsylvania achieves zero emissions by 2050 in the PA-100%RE scenario (see Summary Figure 3).

And powering Pennsylvania's energy needs entirely with renewables by 2050 is not just achievable—it's economic. The PA-100%RE scenario results in energy savings of $134 billion from 2015 to 2050, with $9 billion savings in electric bill and fuel cost savings in 2050 alone. We calculate that as a result of the policies employed in the PA-100%RE scenario, Pennsylvania could see a net increase of nearly 500,000 job-years over the same period.



Summary Figure 3. Pennsylvania's CO_2 emissions inventory

About Synapse

Synapse Energy Economics, Inc. is a research and consulting firm specializing in energy, economic, and environmental topics. Since its inception in 1996, Synapse has grown to become a leader in providing rigorous analysis of the electric power sector for public interest and governmental clients.

About EQ Research

EQ Research LLC provides policy research, analysis and incentive data services to businesses, non-profits and others active in the clean energy sector. EQ tracks and analyzes legislative and regulatory activities in all 50 U.S. states, with a focus on solar energy, distributed generation, energy storage, electric vehicles, net metering and general rate cases.

About Delaware Riverkeeper Network

Mission Statement: The Delaware Riverkeeper Network champions the rights of our communities to a Delaware River and tributary streams that are free-flowing, clean, healthy, and abundant with a diversity of life.

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CONTENTS

1. OVERVIEW

Preventing dangerous climate change requires all communities around the world to do their part to end the emission of greenhouse gases like carbon dioxide (CO_2) from human activities. This study presents a future in which clean energy serves all of Pennsylvania's energy needs by 2050, thereby achieving zero CO_2 emissions from the state's consumption of energy. To this end, Synapse Energy Economics and EQ Research have designed a Pennsylvania 100 percent Renewable—or "PA-100%RE"—future in which the following takes place:

- **Increasing the efficiency of existing energy uses:** Strong energy efficiency measures reduce the use of electricity by existing end-uses, including lighting, refrigeration, and cooling. Electric demand for these uses is reduced by 24 percent in Pennsylvania compared to a future with no efficiency gains.

- **Electrification of non-electric energy consumption:** All transportation, space heating, water heating, and industrial fossil fuel energy use is gradually converted to electric technologies over the next few decades. This electrification makes it possible to power 100 percent of Pennsylvania's energy use by renewables. Inevitably, even after strong efficiency measures are put into place, Pennsylvania's total use of electricity more than triples, while its direct combustion of fossil fuels falls to zero.

- **Greening Pennsylvania's power plants:** By 2050, all coal and nuclear power plants have been retired, and 57 percent of all electricity generated in Pennsylvania comes from renewables. (The remaining 43 percent of electric power produced in Pennsylvania comes from today's existing natural gas generators and is exported for other states' use.) No new natural gas power plants are built in Pennsylvania after the last plant that is currently under construction is completed in 2018, and—unless additional policies are enacted to close natural gas plants sooner—the last natural gas plant would cease operation in the state around 2068.

- **Stimulating the growth of renewables region-wide:** Pennsylvania matches every megawatt-hour (MWh) of electricity that it consumes with a purchase of a renewable energy certificate (REC), ensuring that enough renewable generation occurs within Pennsylvania or in nearby states to supply all of the Commonwealth's needs. These RECs can only be used once—another state cannot also use them for their own clean energy development. As a result, renewable power generation capacity in the wider region is 26 times higher in 2050 than it was in 2015.

Just as it does today, in the future in each of the modeled scenarios, electricity produced in Pennsylvania flows into a power pool for the greater PJM region.[1] Through the purchase of both in- and out-of-state RECs, Pennsylvania both finances and takes responsibility for renewable electric generation sufficient to meet its energy needs. The remaining natural gas generation taking place in Pennsylvania is—in effect—exported to Pennsylvania's neighbors whose demand for carbon polluting electricity continues. An end to all CO_2 emissions from power plants located in Pennsylvania will require either: (1) the retirement of the last natural gas plant in Pennsylvania (this would happen around 2068 assuming a 50-year lifetime and no additional policy measures to expedite retirement); or (2) the end of demand for CO_2-emitting generation in the PJM region as a whole.

Our analysis is restricted to Pennsylvania's consumption of energy and its direct emissions from burning fossil fuels. We have not addressed emissions from fossil fuel extraction, emissions from non-energy sources, upstream or life-cycle emissions, greenhouse gases other than CO_2, or emissions from biomass. In this analysis, we compare two different futures: one in which Pennsylvania continues on its current carbon-emitting trajectory (the "Reference" case) and a second in which Pennsylvania achieves a carbon-free future powered by renewables (the "PA-100%RE" case). While the methodology is our own and includes detailed electric sector modeling, this reports follows the intent of several studies by Mark Z. Jacobson, Mark A. Delucchi, and other scholars at Stanford University.[2]

We begin the study in Chapter 2 with a description of the study's findings showing a future in which all of Pennsylvania's energy needs are served by renewables. Chapter 3 is an examination of Pennsylvania's current energy profile, including the Commonwealth's renewable energy and energy efficiency progress to date. Chapter 4 explores Pennsylvania's options for electrification of transportation, focusing on the transition to EVs. In Chapter 5, we review opportunities for electrification of space and water heating in the residential and commercial sectors, as well as challenges for industrial end uses. Our analysis in Chapter 6 demonstrates the impact of increased energy efficiency. Chapter 7 provides an assessment of permitting and siting issues including policy pathways for achieving the greatest impact. Finally, our modeling assumptions and methodologies are reviewed in an Appendix to the report.

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[1] The PJM power region includes all of Delaware, the District of Columbia, Maryland, New Jersey, Ohio, Pennsylvania, Virginia, West Virginia, and parts of Illinois, Indiana, Michigan, North Carolina, Tennessee, and Kentucky. The PJM system operator coordinates power generation to meet electric demand throughout the region.

[2] Jacobson, M. Z., M. A. Delucchi. 2009. "A Path to Sustainable Energy by 2030." *Scientific American*, November 2009.; Jacobson, M. Z., M. A. Delucchi. 2011. "Providing all global energy with wind, water, and solar polar, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials." *Energy Policy:* 39, 1154-1169.

2. THE PA-100%RE FUTURE

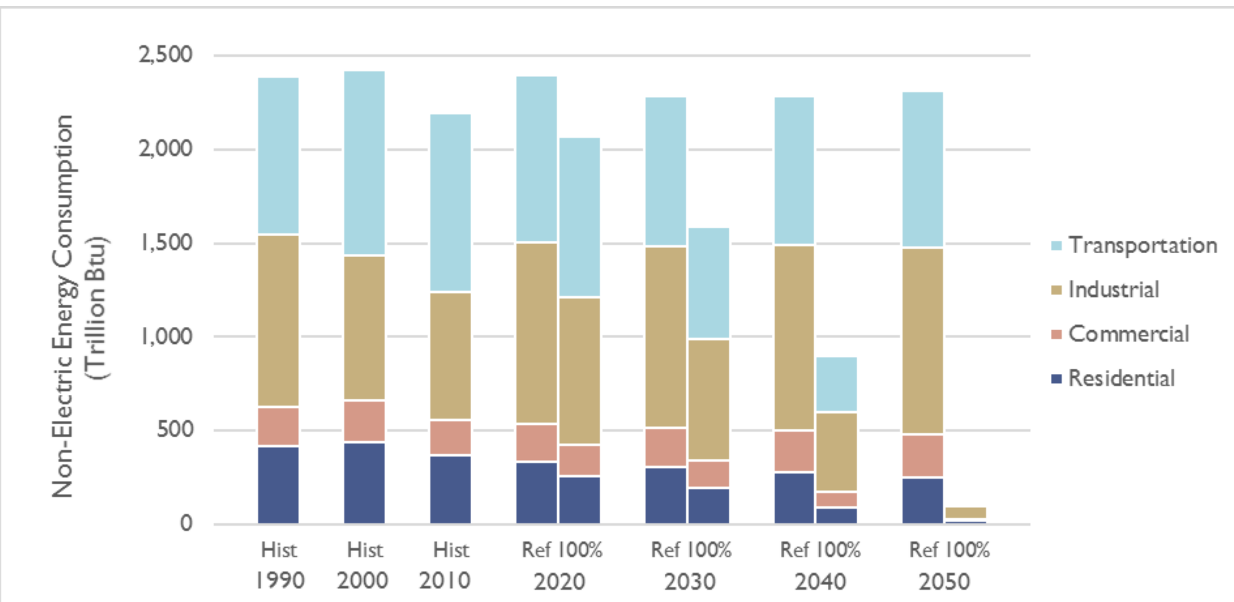
A future in which all of Pennsylvania's energy needs are supplied by renewables will require big changes for the Commonwealth's energy sector. This chapter describes a future modeled in this study to achieve 100 percent renewable energy supply by 2050.

2.1. Electrifying All Energy Uses in Pennsylvania

All fossil fuel non-electric energy uses in Pennsylvania are electrified by 2050 in the PA-100%RE case. This means that all transportation, space and water heating, industrial, commercial and residential uses are gradually converted to electric technologies starting today. By 2050, all of the Commonwealth's energy needs are served by electricity.

Figure 1 shows the energy consumed by sectors in Pennsylvania other than the electric sector. Note that in the PA-100%RE scenario (the Policy scenario, marked "100%" in this figure), a small amount of non-electric energy consumption remains in the year 2050. This residual energy use is biomass consumption in the industrial, commercial, and residential sectors. EIA, the source of this data, considers biomass fuels to have zero greenhouse gas emissions.

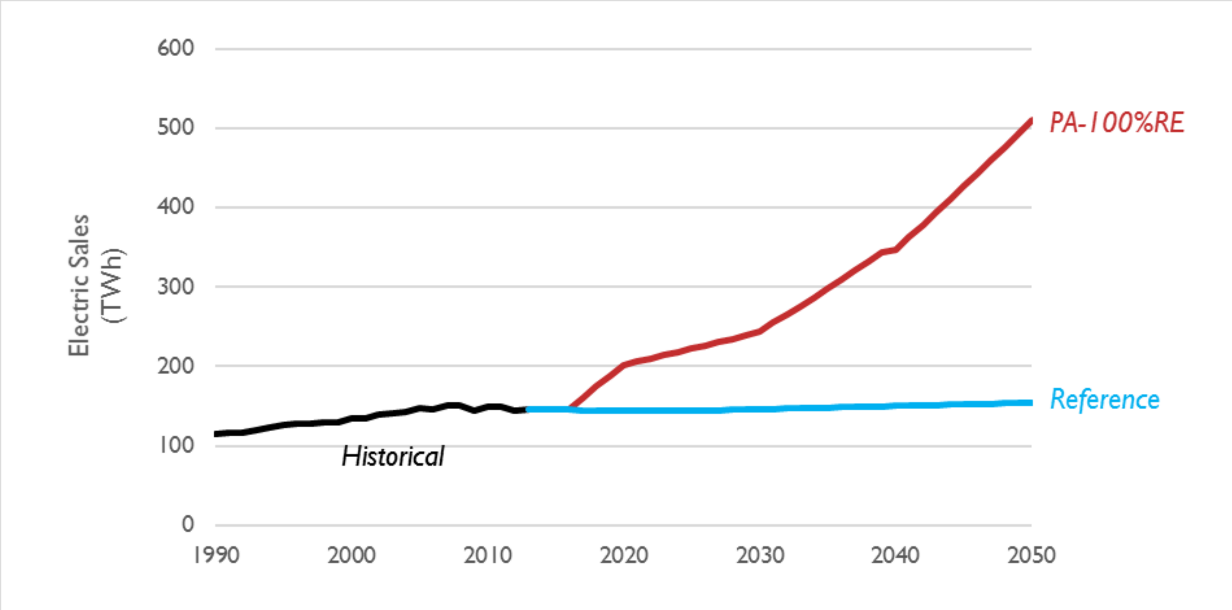
Figure 1. Non-electric energy use in Pennsylvania



2.2. Higher Electric Demand, Even with Efficiency Measures

As transportation, heating and other energy uses are electrified, Pennsylvania's demand for electricity grows steeply over time in the PA-100%RE scenario. Figure 2 depicts the large difference in electric sales between the Reference and PA-100%RE cases resulting from electrification of all fossil fuel non-energy uses.

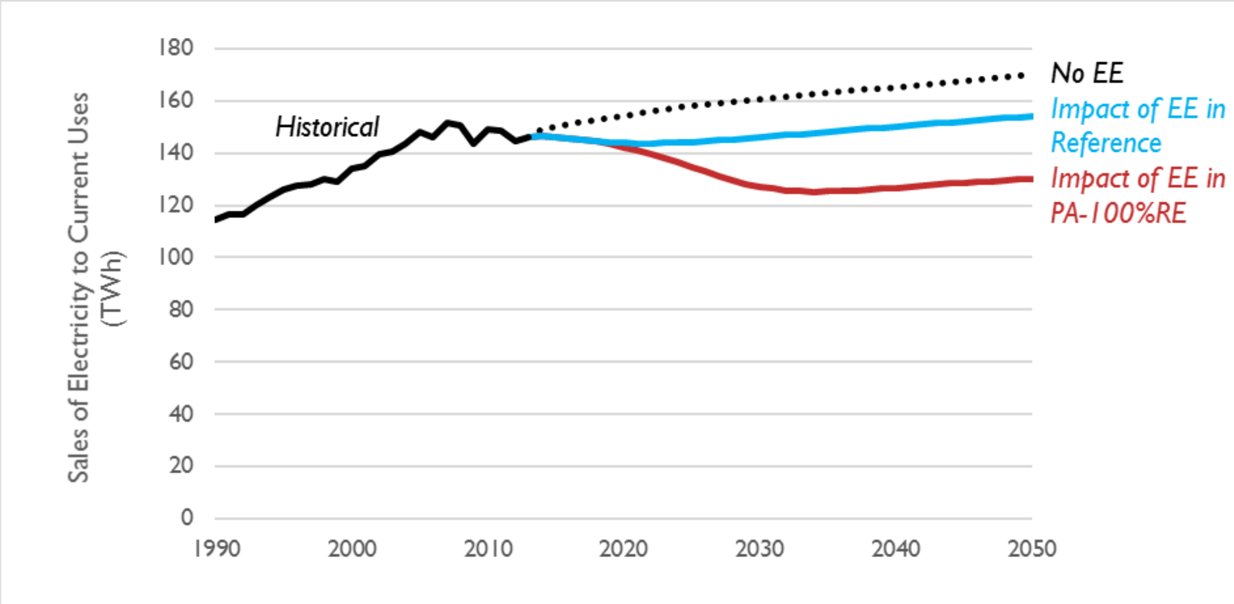
Figure 2. Electric sales in Pennsylvania



Electric technologies are typically more efficient than their non-electric counterparts, so each conversion saves on energy. In addition, we assume that Pennsylvania's current uses of electricity—such as lighting and appliance uses—will be made a little more efficient over time in the Reference scenario and much more efficient in the PA-100%RE policy scenario. Figure 3 shows the impact of energy efficiency on current uses of electricity in both the Reference scenario and in the PA-100%RE scenario. The "No EE" (No Energy Efficiency) trajectory is based on the U.S. Energy Information Administration's expected rate of growth of electric sales for the Pennsylvania, Maryland, and Delaware region.[3] In the Reference case, we assume energy efficiency efforts increase at historical rates for Pennsylvania, reaching a cumulative savings of 9.3 percent over the "No EE" trajectory by 2050. In the PA-100%RE case, we assume energy efficiency efforts are expanded more quickly to be consistent with the rates currently in place in states with the strongest efficiency efforts. This results in a cumulative savings of 23.5 percent (compared to no energy efficiency) by 2050, or two-and-a-half times as much energy efficiency as is implemented in the Reference case.

[3] Annual Energy Outlook (AEO) 2015 Reference case.

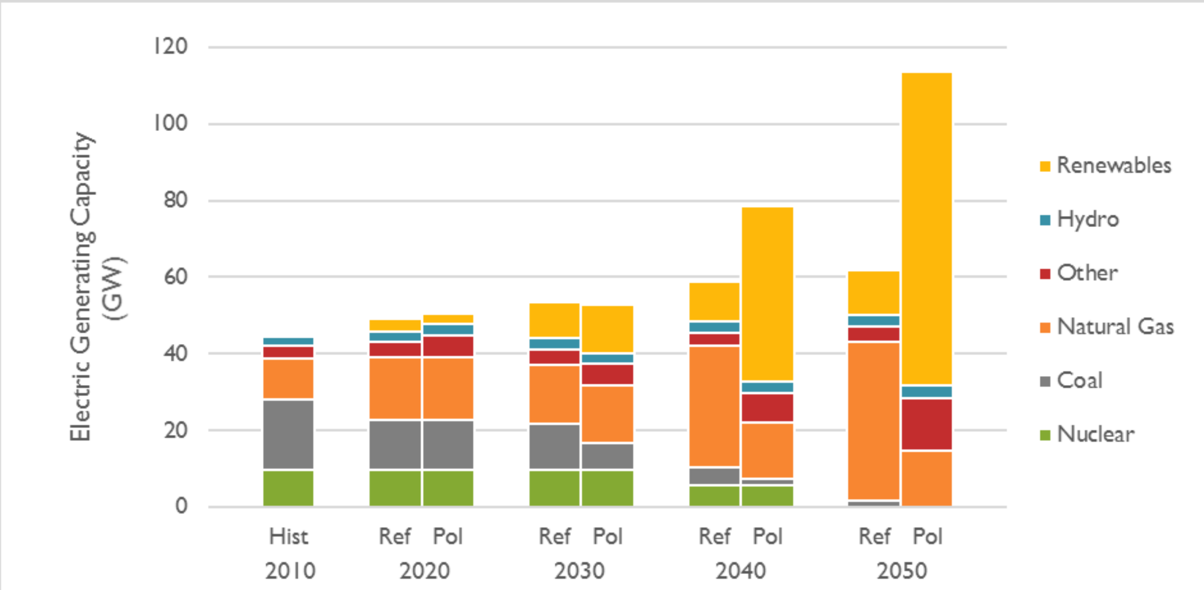
Figure 3. Impact of energy efficiency on current end uses



2.3. Investing in Renewables Region-Wide

To meet this new, higher total electric demand while decreasing greenhouse gas emissions, Pennsylvania purchases an increasing number of in-state and out-of-state RECs, and the composition of electric generating resources in both Pennsylvania and the PJM region as a whole changes dramatically. Coal-fired power plants are retired more rapidly, no new natural gas power plants are built in the state, and Pennsylvania's renewable generating capacity increases 100-fold between 2010 and 2050 (see Figure 4). Through these REC purchases Pennsylvania pays for and takes ownership of renewable generation throughout the PJM region; remaining fossil fuel generation within the state is effectively exported to neighboring states that still have a demand for it.

Figure 4. Electric generating capacity in Pennsylvania



Note: In this figure, "Ref" refers to the [reference] scenario and "Pol" shows the [PA-100%RE] scenario. 2010 Historical ("Hist") levels are shown for comparison.

Pennsylvania's electric generating capacity for onshore wind, utility solar photovoltaics (PV), and rooftop solar PV grows rapidly in the PA-100%RE case (see Table 1).

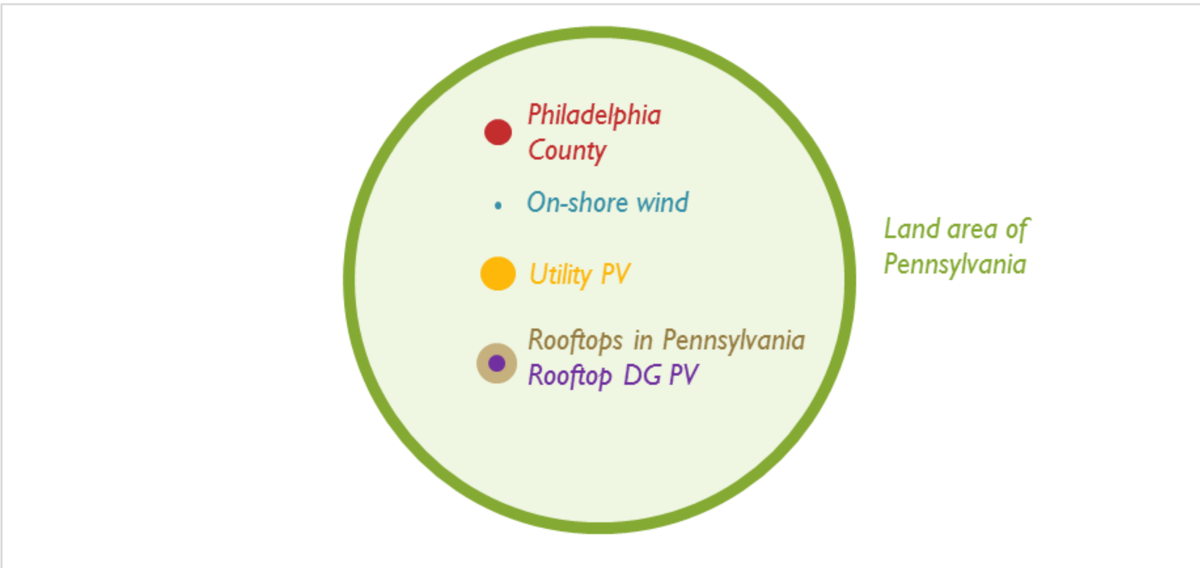
Table 1. Electric generating capacity (GW): 2015 actual and 2050 in the PA-100%RE scenario

	2015	2050
Onshore Wind		
Pennsylvania	1.4	9.2
PJM	5.2	36.3
Utility PV		
Pennsylvania	<0.1	50.4
PJM	1.6	141.5
Rooftop PV		
Pennsylvania	0.3	22.5
PJM	1.6	44.4

Even the amount of renewables capacity built in the PA-100%RE scenario, however, is just a part of the overall technical potential for these resources. Here, technical potential refers to the total possible amount of energy that can be produced from a resource given geographic and system constraints, but without any consideration of its economics. In the PA-100%RE scenario, wind capacity built by 2050 represents about 77 percent of the technical potential, rooftop solar PV represents 52 percent of the technical potential, and utility solar PV capacity built represents just 6 percent of the technical potential.[4]

As depicted in Figure 5, utility solar PV and wind farms built in the PA-100%RE case take up just a small share of Pennsylvania's total land area (the largest green circle). Similarly, rooftop solar PV uses only a part of the total potential roof area in the Commonwealth. Philadelphia County's land area and the area currently occupied by residential, commercial, and industrial rooftops in Pennsylvania are included for context.

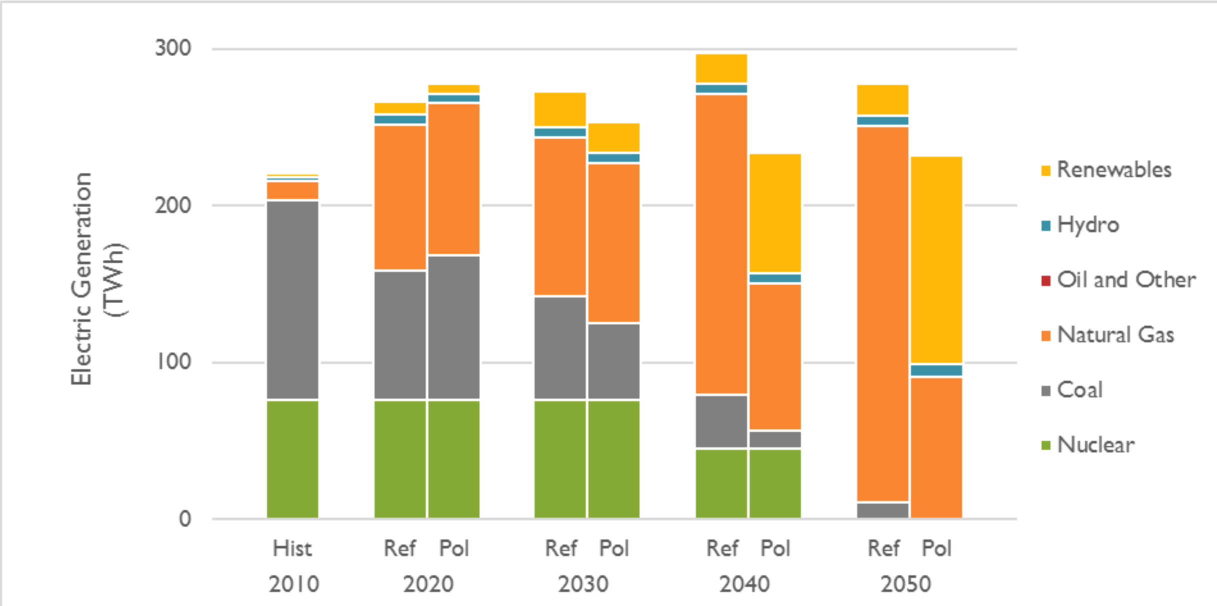
Figure 5. Land footprint taken by renewables in 2050



By 2050, in the PA-100%RE scenario, 57 percent of all electricity generated in Pennsylvania comes from renewables (see Figure 6). (The remaining 43 percent of Pennsylvania's electric generation is produced using natural gas and is effectively exported out of state.) Pennsylvania generation is not, however, large enough to satisfy the Commonwealth's new, far greater demand for electricity in the PA-100%RE case (sales reach 510 TWh in 2050).

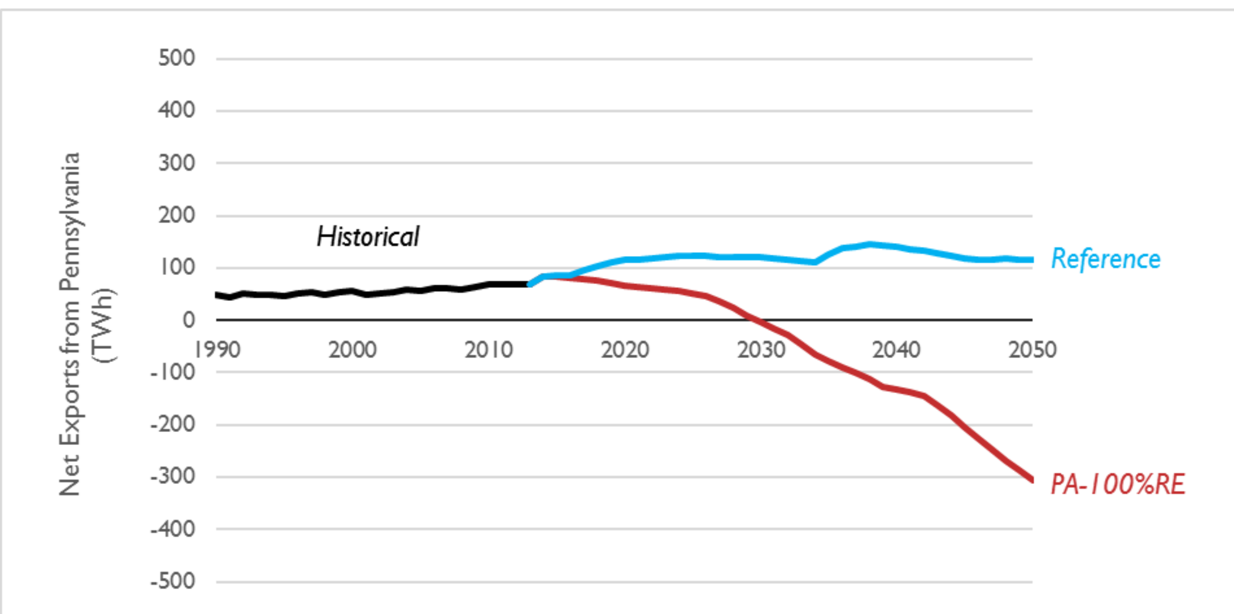
[4] National Renewable Energy Laboratory (NREL). "Estimating Renewable Energy Economic Potential in the United States: Methodology and Initial Results," www.nrel.gov/docs/fy15osti/64503.pdf and "Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment," www.nrel.gov/docs/fy16osti/65298.pdf.

Figure 6. Electric generation in Pennsylvania



Achieving complete decarbonization in Pennsylvania by 2050 requires imported renewable generation from other members of the PJM electric operation system. In both the Reference and PA-100%RE cases, Pennsylvania exports fossil fuel power electricity to the rest of PJM. In the PA-100%RE case, however, Pennsylvania becomes a big net importer: importing more renewable-powered electricity than its export of fossil fuel power electricity (see Figure 7).

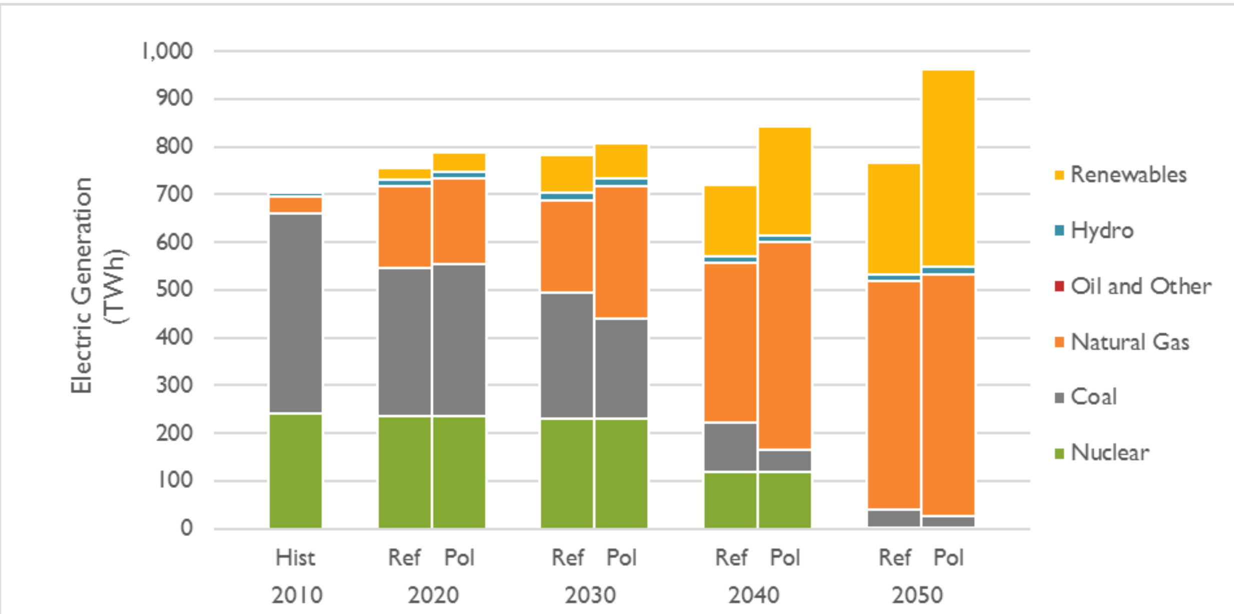
Figure 7. Net electricity exports from and imports to Pennsylvania



Note: In this figure, negative numbers indicate overall net imports of electricity to the state of Pennsylvania, whereas positive numbers indicate overall net exports of electricity from Pennsylvania to neighboring states.

Just as it is today, in both of our scenarios, developers and utilities may build renewables anywhere in the PJM region to meet Pennsylvania's renewable portfolio standard. In response to increased demand for both electricity and RECs in the PA-100%RE case, Pennsylvania stakes a claim to much of the greater share of the region's renewable generation, and the PJM region (other than Pennsylvania) builds 138 new GW of renewables from 2010 to 2050 to supply both Pennsylvania and the existing renewable portfolio standards in other PJM states. Figure 8 presents the impact that the PA-100%RE scenario has on the growth in renewables over time in the larger PJM region as a whole. Pennsylvania buys 89 percent of all PJM RECs in the PA-100%RE case (compared to 24 percent in the Reference case) and stimulates the growth of renewables throughout the region. By 2050, other states continue to rely on natural gas for electricity generation. These states will need to implement policies like the kind used by Pennsylvania in the PA-100% case in order to further reduce the consumption of fossil fuels.

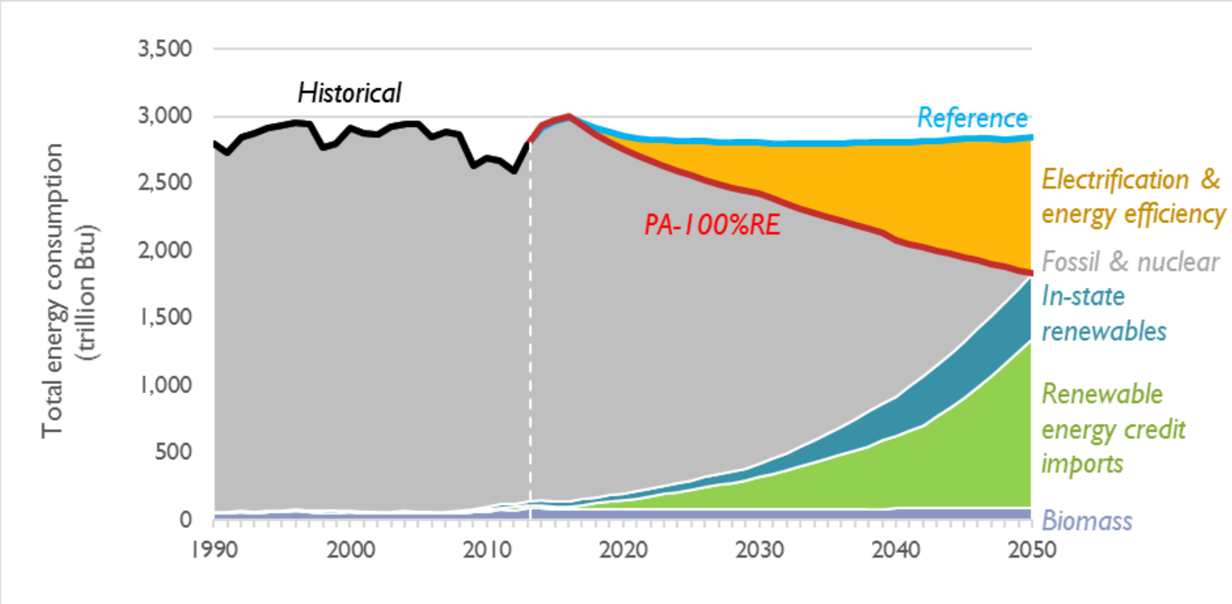
Figure 8. Electric generation in PJM



2.4. Zero Greenhouse Gas Emissions for Pennsylvania

Overtime, all energy use in Pennsylvania is electrified and all electricity is generated by renewable resources. By 2050, much of Pennsylvania's energy consumption is provided through both in- and out-of-state purchases of renewables. Figure 9 shows how the shares of Pennsylvania's energy consumption from various electric and non-electric fuel sources changes over time. Pennsylvania's overall energy use decreases by one-third as a result of end-use electrification and energy efficiency measures.

Figure 9. Total energy consumption in Pennsylvania in the PA-100%RE scenario



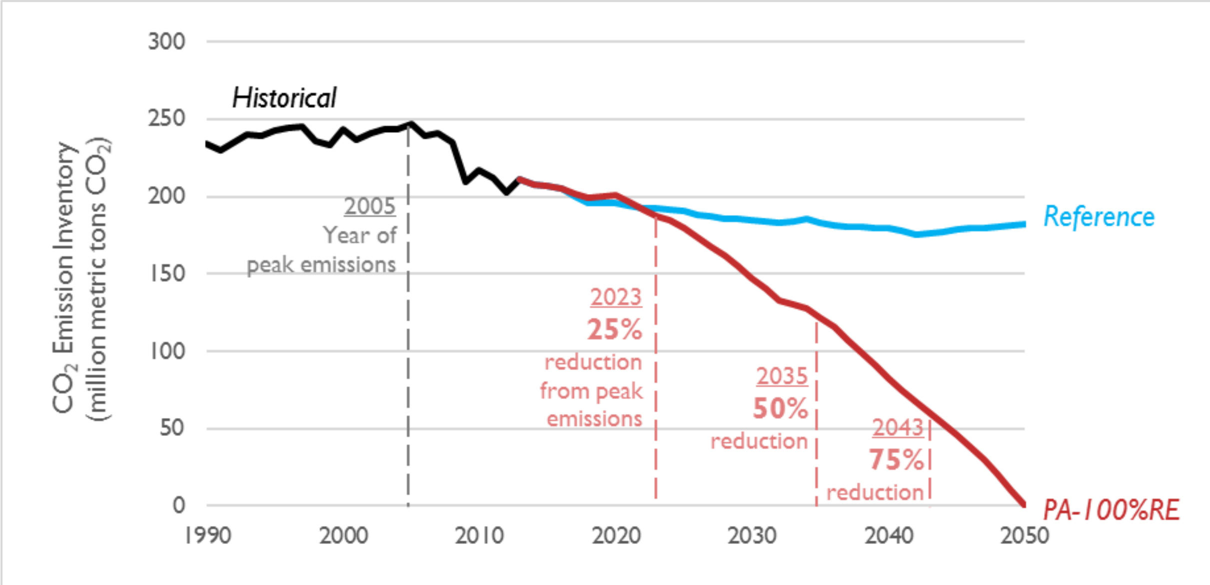
Note that although Pennsylvania continues to host CO_2-emitting natural gas generators through 2050, the electricity produced by Pennsylvania's remaining natural gas power plants is effectively exported. Sufficient in- and out-of-state RECs are purchased to fully match the amount of electricity used by Pennsylvanians offsetting emissions from the remaining CO_2-emitting sources. Because Pennsylvania shares a jointly coordinated electric power pool with the other PJM states, either a change in the demand for fossil fuel-fired electric generation in the Commonwealth's neighboring states, or separate policies directed at energy production would be required to ensure that Pennsylvania no longer hosts emitting generators. Until that time, even in the PA-100%RE scenario, energy extraction and production facilities within Pennsylvania result in both direct emission of carbon dioxide and upstream emissions from non-CO_2 greenhouse gases including methane.

Pennsylvania's CO_2 emissions (shown in Figure 10) are its:

- emissions from non-electric energy sources, plus
- emission from electric generation physically located in Pennsylvania, less
- emissions exported along with exported electricity.

Pennsylvania's purchase of RECs ensures that the Commonwealth is awarded credit for the renewable generation that it provides incentives for regardless of where they are located in the PJM region. As a result, Pennsylvania's emissions fall from over 250 million metric tons in 2015 to zero in 2050 in the PA-100%RE scenario.

Figure 10. Pennsylvania's CO_2 emissions inventory



Each of the strategies employed in the PA-100%RE case has a different impact on the emissions that would have occurred in the Reference case but are instead avoided (see Table 2).

Table 2. Share of 2050 CO_2 emissions reductions (difference between Reference and PA-100%RE cases)

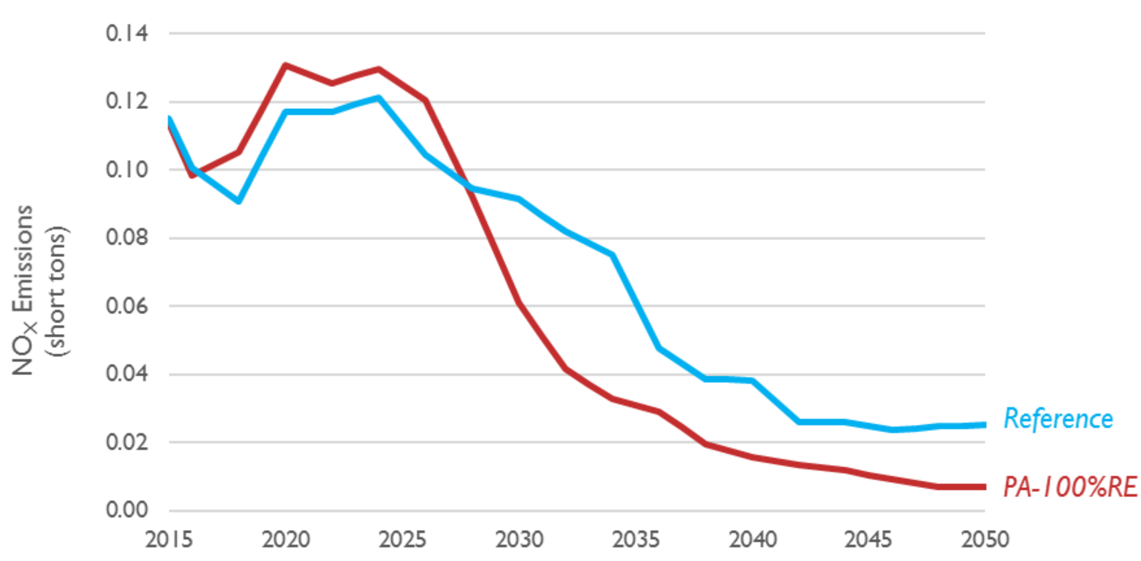
	Share of 2050 CO_2 reductions
Electric	**28%**
Renewables	25%
Electric energy efficiency	3%
Residential and Commercial	**14%**
Space heating electrification (heat pumps)	7%
Water heating electrification	3%
Other electrification	4%
Industrial	**29%**
Industrial electrification	29%
Transportation	**29%**
Motor gasoline electrification	14%
Other transportation electrification	13%
Airplane electrification	2%

Industrial electrification is one of the largest single drivers of emission reductions; by itself this measure reduces emissions by nearly 30 percent compared to Reference case emissions. Other strategies that achieve major emissions reductions include motor gasoline and other transportation electrification. Like industrial electrification, these strategies account for especially large shares of total emission reductions because they impact end-uses that do not experience substantial emission reductions in the Reference case. The "Renewables" category is also a large driver of emissions reductions—this category represents both the in-state renewables and RECs purchased to power existing electric end-uses, and the emissions displaced from newly-electrified sectors of the economy.

Electric sector direct emissions of criteria pollutants (not including any upstream impacts from extraction), including nitrogen oxides (NO_X), sulfur dioxides (SO_2), and mercury (Hg) fall in both the Reference and PA-100% RE scenarios (see Figure 11, Figure 12, and Figure 13). These pollutants have been demonstrated to cause smog and acid rain, as well as increased negative health effects, including asthma and heart attacks. At the same time, water consumption and water withdrawals also decrease in the PA-100%RE case (see Figure 14 and Figure 15). All five of the environmental impacts depicted here show dramatic improvements even in the Reference scenario as a result of scheduled coal retirements and environmental retrofits at power plants. These environmental impacts are reduced even more rapidly in the PA-100%RE scenario than in the Reference scenario.

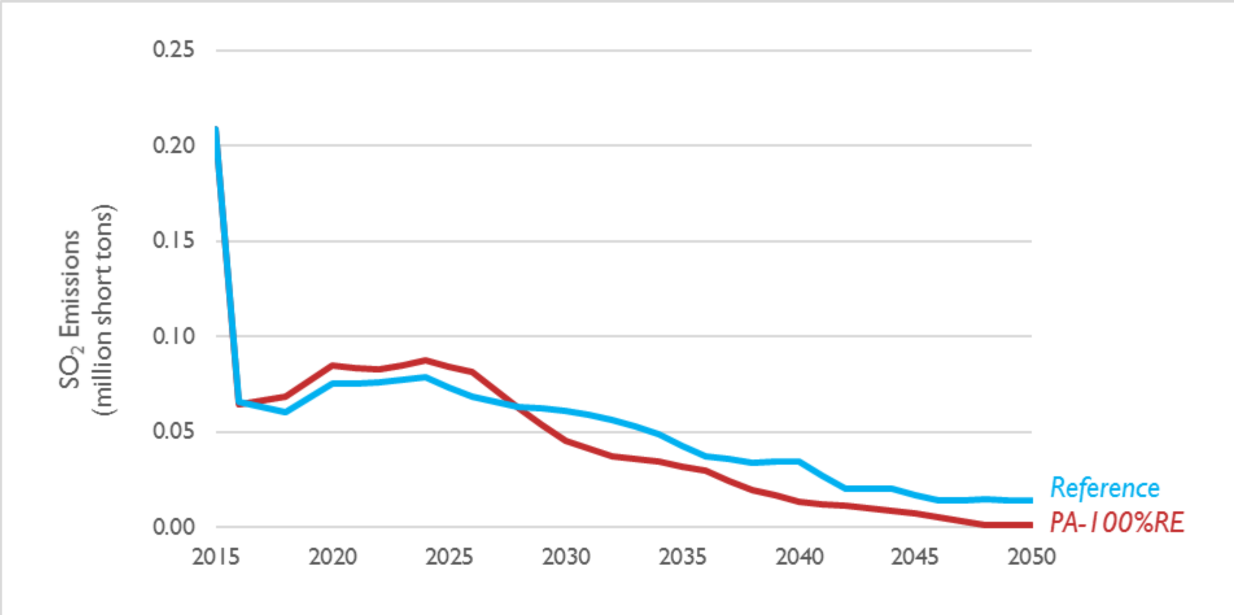
Electrification of load at this scale could take decades at an aggressive pace. As a result, in the early years of the study period, electrification of load outpaces the transformation of the power sector, and criteria pollutant emissions increase. This is an unfortunate but temporary side-effect of the need for rapid and comprehensive change at so many point sources. Despite the modest increase in electric sector criteria pollutant emissions, these sources of load – representing point sources of fossil fuel combustion across the state – are no longer emitting those same criteria pollutants at the point of use.

Figure 11. NO_X emissions from Pennsylvania's electric sector



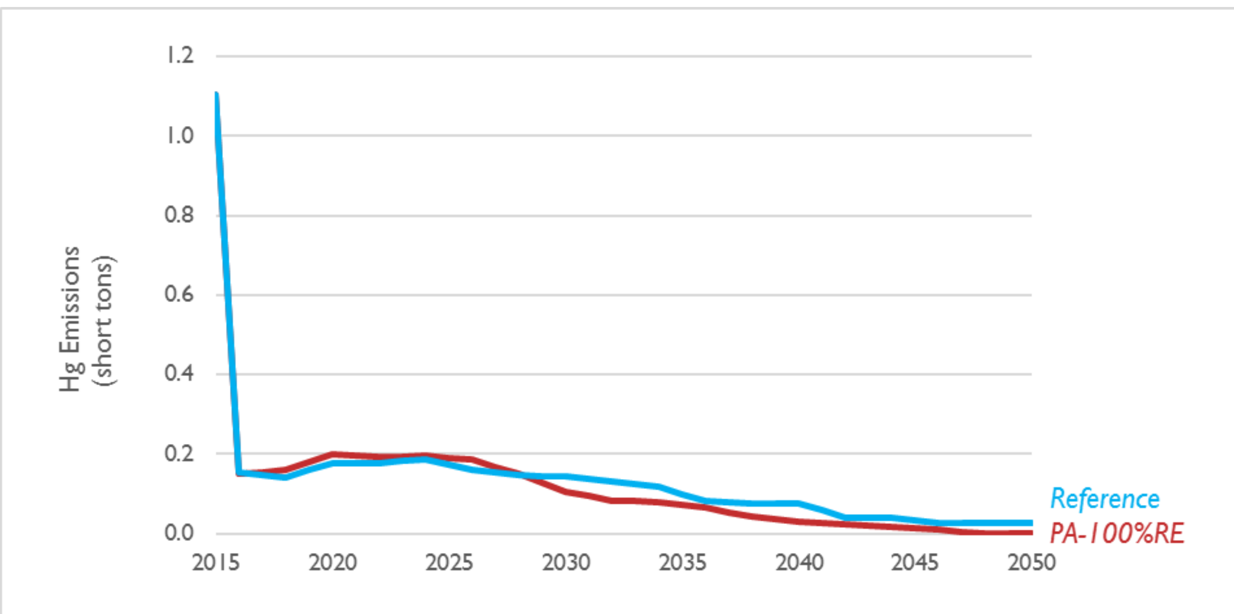
Note: Data in this figure only contains NO_X emissions from electric generators. It does not include NO_X emissions from the transportation, residential, commercial, or industrial sectors. As a result, this figure does not quantify the significant NO_X emission reductions from non-electric sources, which together make up around 80 percent of all NO_X emissions.

Figure 12. SO_2 emissions from Pennsylvania's electric sector



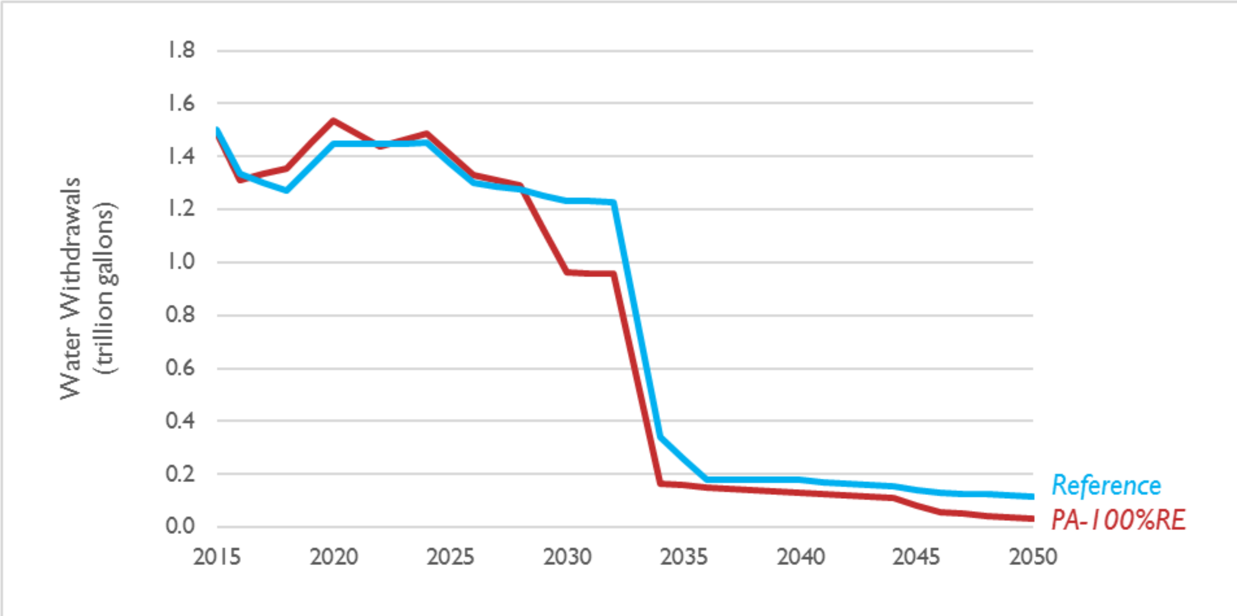
Note: Data in this figure only contains SO_2 emissions from electric generators. It does not include SO_2 emissions from the transportation, residential, commercial, or industrial sectors.

Figure 13. Mercury (Hg) emissions from Pennsylvania's electric sector



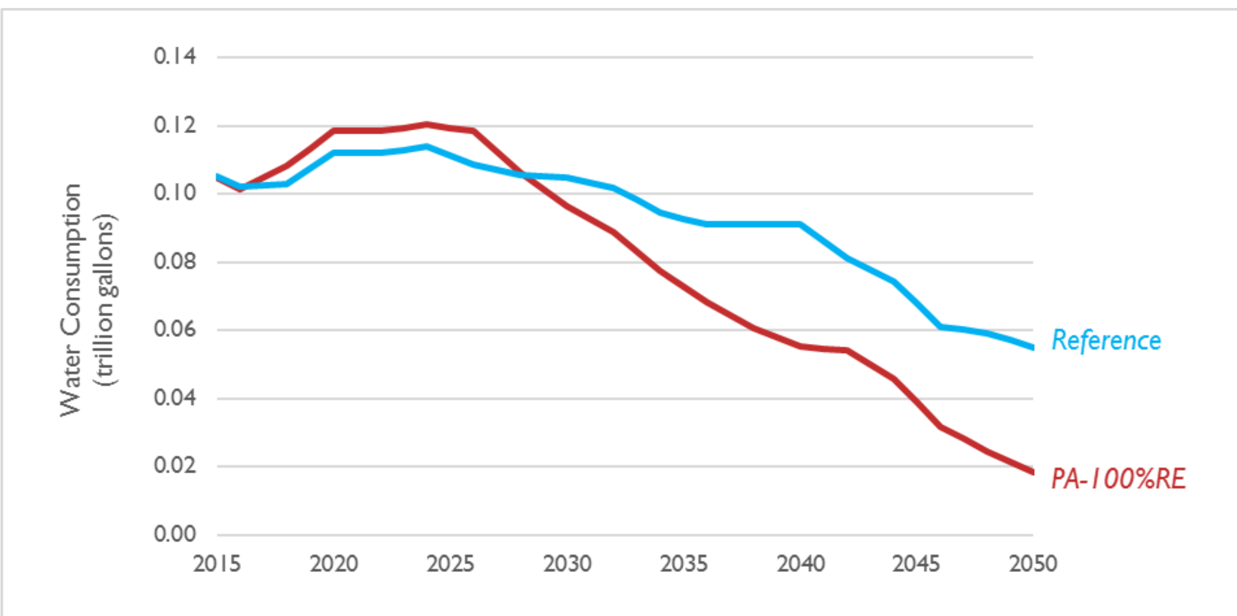
Note: Data in this figure only contains mercury emissions from electric generators. It does not include mercury emissions from the transportation, residential, commercial, or industrial sectors.

Figure 14. Water withdrawals in Pennsylvania's electric sector



Note: This figure does not include water withdrawals associated with upstream uses, including hydraulic fracking.

Figure 15. Water consumption in Pennsylvania's electric sector

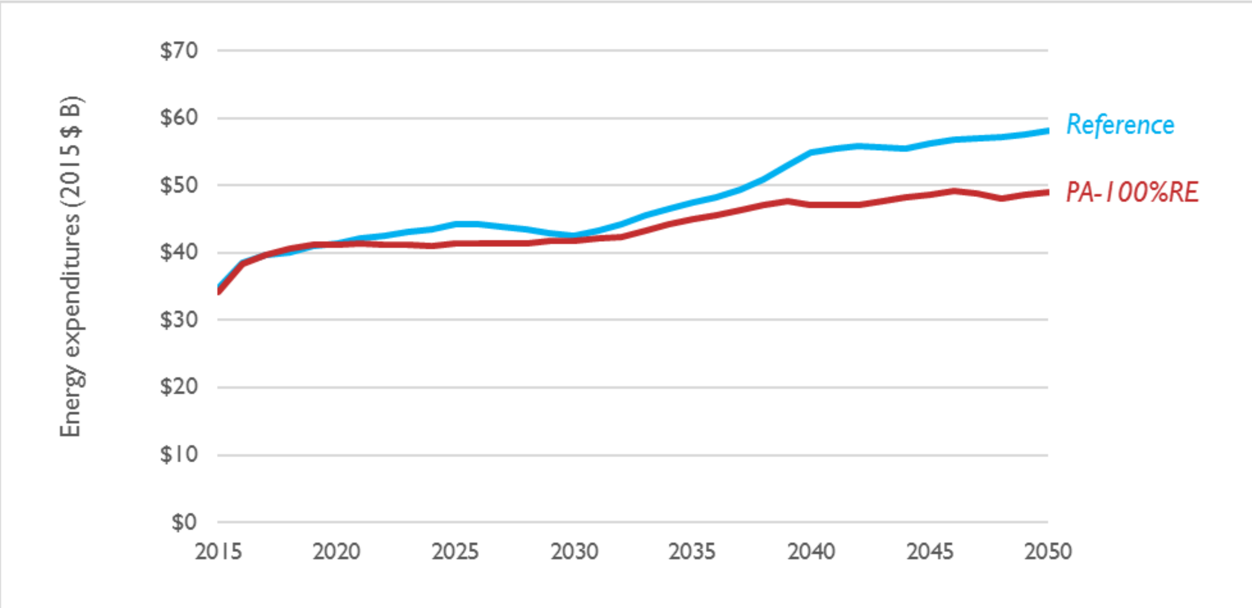


Note: This figure does not include water consumption associated with upstream uses, including hydraulic fracking.

2.5. Lower Energy Expenditure with Renewables and Efficiency

Energy expenditures are lower in the PA-100%RE case than in the Reference case. Electric sector and fuel cost savings included in our modeling amount to $134 billion over the 2015 to 2050 period, and $9 billion in 2050 alone in electric bill and fuel cost savings (see Figure 16).

Figure 16. Energy expenditures in Pennsylvania



The expenditures shown here include costs of building new electricity infrastructure in Pennsylvania, costs of importing electricity to meet reliability, and fuel expenditures in the non-electric sectors but the cost of implementing new policies or technologies that result in decarbonization are limited in this analysis to the costs of electric energy efficiency and renewables. For example, in the transportation sector fuel and electric costs (including new renewables) are included but potentially higher costs of EVs and new non-electric infrastructure are not. This additional investment would have a clear cost, but would also carry benefits because additional money spent to build new infrastructure to electrify the transportation, heating and industrial sectors and build new renewable resources—not modeled here—would stimulate the state and regional economy increasing economic value, tax revenue, and jobs.

At the same time Pennsylvanians save money on energy expenditures, they accrue the benefits of job gains resulting from the PA-100%RE scenario. In comparison to the reference case, in the PA-100%RE scenario we calculate that between 2016 and 2050, Pennsylvania could see a net increase of nearly 500,000 job-years, or an average of 14,300 job-years per year during the study period.[5] These jobs result from new investment in renewables and energy efficiency.

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[5] A "job-year" is equivalent to the employment of one full-time worker for the period of one year.

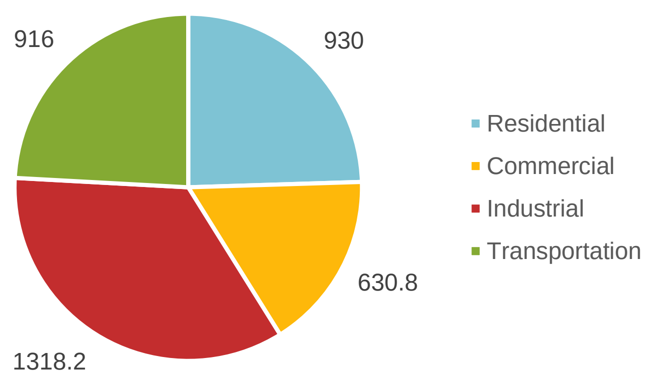
3. PENNSYLVANIA BACKGROUND

Pennsylvania is a notable energy producer, electricity exporter, and electricity market pioneer. As the sixth most populous state with 12.8 million residents,[6] Pennsylvania was the third-largest energy producing state in the United States in 2013 behind Texas and Wyoming, producing 5,880 trillion BTU.[7] Pennsylvania is also the largest electricity exporter in the nation, with nearly one-third of energy generated exported;[8] in-state electric consumption totaled 3,795 trillion BTU in 2013.[9]

3.1. Energy Sector Overview

As presented in Figure 17, the industrial sector is the largest energy user in Pennsylvania, highlighting the significant presence of energy-intensive industries in the state.

Figure 17. Pennsylvania energy use by sector (trillion BTU), 2013



Source: EIA, "Table F30: Total Energy Consumption, Price, and Expenditure Estimates, 2013." Accessed April 13, 2016.

Greenhouse gas emissions

Most greenhouse gas emissions related to energy come from electricity generation, transportation, and industrial uses in Pennsylvania (see Figure 18). In its Draft Climate Change Action Plan, the Pennsylvania Department of Environmental Protection (PA DEP) estimated 2012 gross greenhouse gas emissions at

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[6] U.S. Energy Information Administration (EIA). "Pennsylvania: Profile Data." Accessed April 13, 2016. www.eia.gov/state/data.cfm?sid=PA#ConsumptionExpenditures.

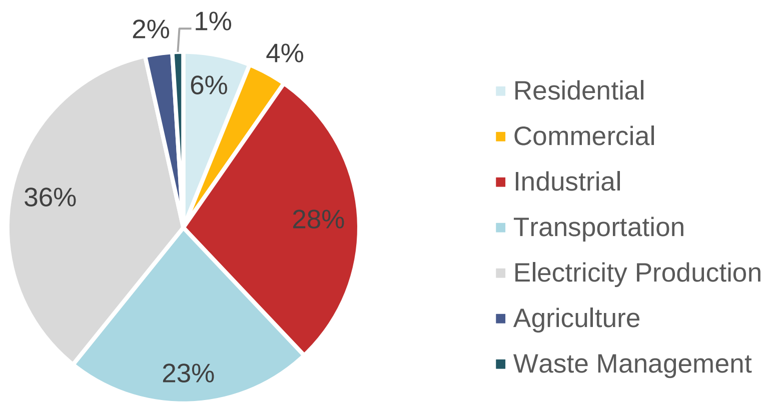
[7] EIA. "Rankings: Total Energy Production, 2013." Accessed April 13, 2016. www.eia.gov/state/rankings/?sid=PA#series/101.

[8] Pennsylvania Department of Environmental Protection (PA DEP). 2015. *Draft 2015 Climate Change Action Plan*, 9. www.portal.state.pa.us/portal/server.pt/document/1612924/draft_2015_climate_change_action_plan_update_(10-21-2015)_pdf.

[9] EIA, Pennsylvania: Profile Data.

287.38 MMTCO2e. This was an 11 percent decrease relative to 2000 due mainly to carbon emissions from electric generation by coal being increasingly replaced with natural gas.[10]

Figure 18. Pennsylvania greenhouse gas emissions by sector, 2015 (estimated)



Source: Pennsylvania Department of Environmental Protection. Draft 2015 Climate Change Action Plan.

Energy production

Historically a coal mining state, Pennsylvania produced 6 percent of the nation's coal in 2014.[11] More recently, the widespread adoption of hydraulic fracturing drilling techniques has allowed drillers to gain access to natural gas in the Marcellus and Utica shale formations. This has rapidly propelled natural gas production in Pennsylvania, which now trails only Texas in annual production.[12]

Electricity market

Pennsylvania was one of the first states to deregulate its electricity market and offer customers choice in their electric generation supplier. Since then, more than 2 million customers have switched electric generation suppliers, representing 86 percent of industrial customers, 45 percent of commercial customers, and 34 percent of residential customers.[13]

Eleven investor-owned electric distribution companies (EDCs) deliver electricity to most Pennsylvania customers. Cooperatives and municipal systems provide service to several rural and urban areas. This

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[10] PA DEP, Draft 2015 Climate Change Action Plan, 9. Note: Greenhouse gas emissions, which include a Forestry and Land Use sector sink of 36.26 MMTCO2e, were estimated at 253.12 MMTCO2e.

[11] EIA. "Rankings: Coal Production, 2013." Accessed April 13, 2016. www.eia.gov/state/rankings/?sid=PA#series/48.

[12] EIA. "Rankings: Natural Gas Marketed Production, 2014." Accessed April 13, 2016. www.eia.gov/state/rankings/?sid=PA#series/47.

[13] Corbett, T. 2014. *Energy = Jobs: Pennsylvania State Energy Plan*, 34.

includes 14 electric distribution cooperatives in Pennsylvania and Sussex County, New Jersey serving 600,000 rural customers.[14]

The 11 investor-owned EDCs regulated by the Pennsylvania Public Utility Commission (PUC) are:

- Citizens' Electric Company
- Duquesne Light Company
- Metropolitan Edison Company (FirstEnergy)
- Pennsylvania Electric Company (FirstEnergy)
- Pennsylvania Power Company (FirstEnergy)
- PPL Electric Utilities Corporation
- PECO Energy Company (Exelon)
- Pike County Light & Power Company (Orange & Rockland Utilities Inc.)
- UGI Utilities Inc. – Electric Division
- Wellsboro Electric Company
- West Penn Power Company (FirstEnergy)[15]

Pennsylvania is wholly within the footprint of the PJM Interconnection, LLC, a regional transmission organization that also serves all or part of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Tennessee, Virginia, West Virginia, and the District of Columbia. Headquartered in Valley Forge, Pennsylvania, PJM is one of the largest wholesale electricity markets in the world.

Electric generation

Pennsylvania is the third-largest generator of electricity in the nation and currently has approximately 200 major electric generation facilities.[16] With nine nuclear reactors at five power plants, Pennsylvania generated a majority of its electricity from nuclear power in 2015, producing more than any state except for Illinois (see Figure 19 and Figure 20).[17] Coal and natural gas account for most of the balance of electricity generation. Natural gas has grown from only 1 percent of electric generation in 2000 to more

[14] Pennsylvania Rural Electric Association. "Electric Cooperatives in Pennsylvania and New Jersey." Accessed April 13, 2016. www.prea.com/Content/member-cooperatives.asp.

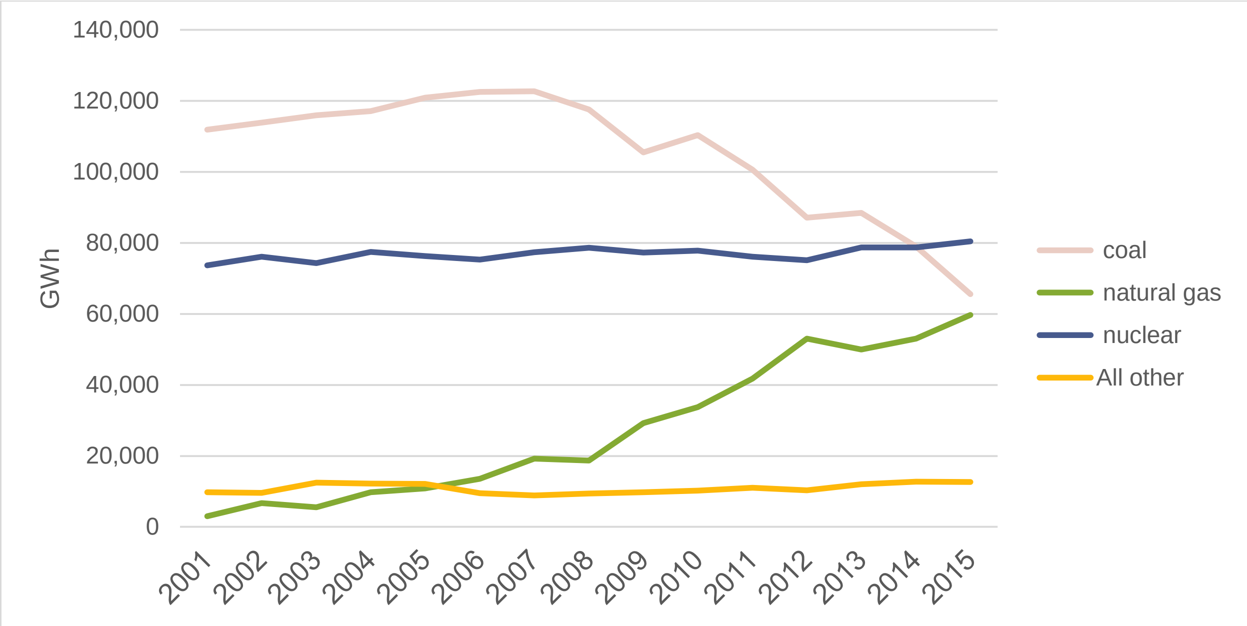
[15] Pennsylvania Public Utilities Commission (PA PUC). 2015. *Electric Power Outlook for Pennsylvania*. www.puc.pa.gov/General/publications_reports/pdf/EPO_2015.pdf.

[16] PA DEP, Draft 2015 Climate Change Action Plan, 9.

[17] Corbett, T, Pennsylvania State Energy Plan, 19.

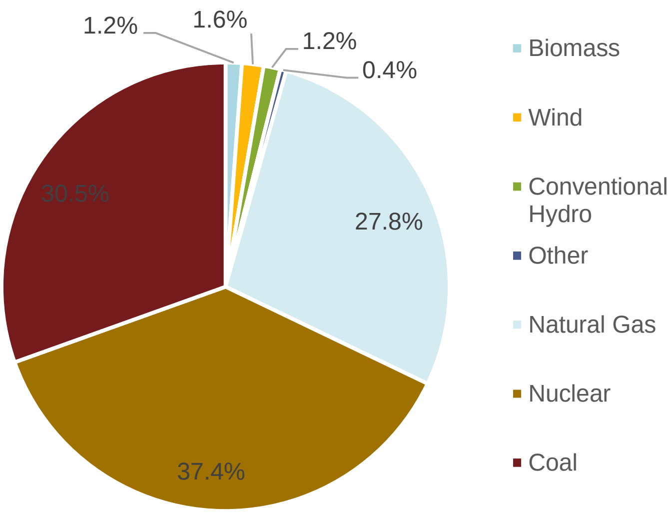
than 27 percent in 2015, with coal declining from 57 percent of generation to just above 30 percent during the same period.[18]

Figure 19. Sources of electric generation in Pennsylvania, 2000-2015



Source: EIA. "Electricity Data Browser"

Figure 20. Pennsylvania electricity sources, 2015



Source: U.S. Department of Energy Efficiency & Renewable Energy. "State & Local Data."

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[18] Corbett, T, Pennsylvania State Energy Plan, 9.

As shown in the Table 3 below, coal led all generation sources as recently as 2014 (the most recent year for which complete data was available) in terms of installed capacity (14.2 GW) and generation, leading natural gas (11.9 GW) and nuclear (9.6 GW).

Table 3. Pennsylvania electric capacity and generation, 2014

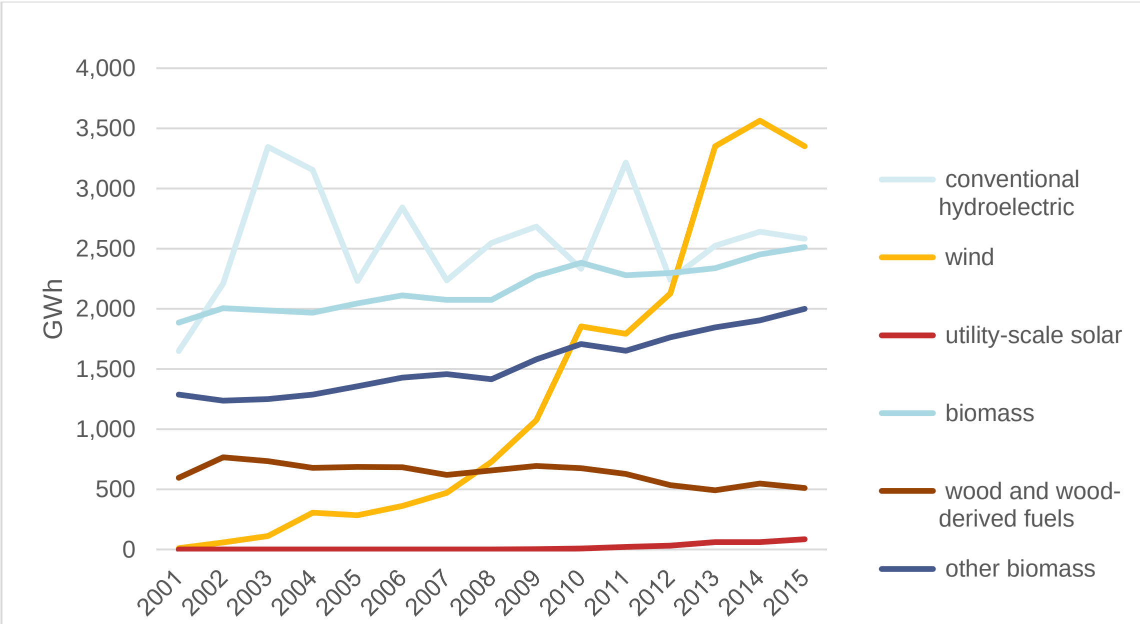
Source	Capacity (MW)	Generation (MWh)
Coal	14,214	78,985,629
Hydroelectric	893	2,641,157
Natural gas	11,926	53,021,235
Nuclear	9,641	78,714,659
Other	20	900,134
Other biomass	459	1,904,224
Other gas	100	490,777
Petroleum	2,380	803,004
Pumped storage	1,583	(578,653)
Solar (Utility-Scale)	42	62,392
Wind	1,334	3,564,730
Wood	121	549,077
Total	42,723	**221,058,365**

Source: EIA. "Table 4: Electric Power Industry Capability by Primary Energy Source, 1990 Through 2014: Pennsylvania." and "Table 5: Electric Power Industry Generation by Primary Energy Source, 1990 through 2014."

As depicted in Figure 21, while currently comprising a small proportion of electricity generation, renewable energy sources are growing. Pennsylvania's alternative energy portfolio standard requires annual increases in the proportion of electricity generated by alternative energy. In 2014, approximately 3.2 percent of electricity was generated from wind, water, and solar sources. An additional 1.5 percent comes from biomass, biogas, landfill gas, and coal mine methane.[19]

[19] PA PUC. 2016. *2014 Annual Report: Alternative Energy Portfolio Standards Act of 2004*.

Figure 21. Renewable energy electricity generation in Pennsylvania, 2001-2015



Source: EIA. "Electricity Data Browser." Note that distributed solar is omitted from the chart due to a lack of data availability; see section "Distributed Generation" below for details.

The 258 MW of total solar PV installed in Pennsylvania ranks it 15th in the United States[20]; however, the state ranked only 25th and 24th in 2014 and 2015, respectively, in terms of new capacity additions.[21] This indicates that while originally a solar leader, Pennsylvania has recently been adding new solar capacity at a slower rate than about half of all other states and will fall in the state rankings in the future if recent trends continue.

Retail electric sales

Electric distribution companies and suppliers accounted for 97 percent of retail electric sales in 2014, with cooperatives (2 percent) and municipal utilities (1 percent) contributing only a small portion of total sales.[22] Electricity prices for residential ($0.1412/kWh) and industrial ($0.0693) customers are slightly higher than the U.S. average, whereas commercial ($0.093/kWh) customers pay slightly below the national average.[23] As shown in Figure 22, the residential and commercial sectors each account for a

[20] Solar Energy Industries Association. "Pennsylvania Solar." Accessed April 13, 2016. www.seia.org/state-solar-policy/pennsylvania.

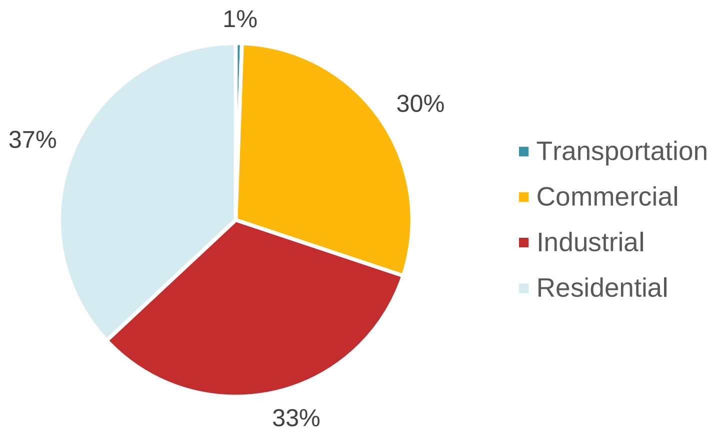
[21] GTM Research. 2016. U.S. Solar Market Insight: 2015 Year-in-Review: Executive Summary, 9.

[22] EIA. "Table 9. Retail Electricity Sales Statistics, 2014: Pennsylvania." Accessed April 14, 2016. www.eia.gov/electricity/state/pennsylvania/.

[23] EIA, Pennsylvania: Profile Data.

slightly higher proportion of retail sales than the industrial sector, which consumes most of its energy from other energy sources.

Figure 22. Pennsylvania electricity sales by sector, 2014



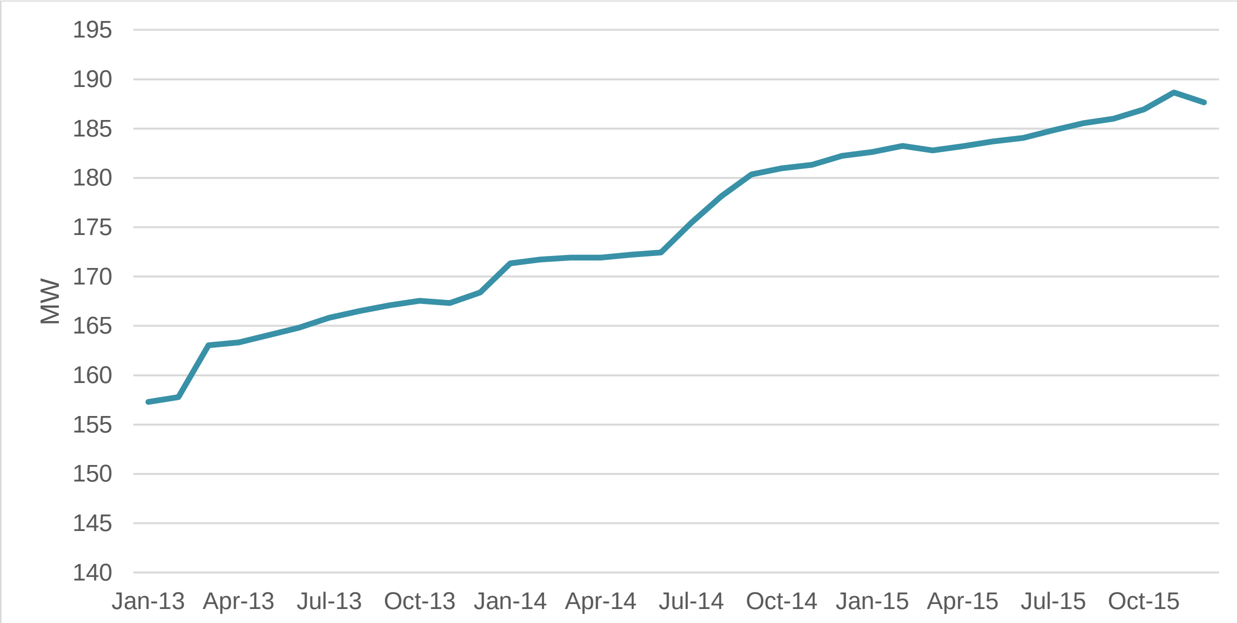
Source: EIA. "State Energy Data System."

Distributed generation

While not yet a substantial proportion of electricity generated in Pennsylvania, distributed generation capacity has grown steadily in recent years. The vast majority of the 220 MW of net-metered distributed generation systems are solar PV, with only 1 MW of distributed wind and 32 MW of other distributed energy resources in Pennsylvania. Specifically, there were 9,578 solar net metering customers with a total of 188 MW of capacity through the end of 2015 (see Figure 23). EIA estimates distributed PV generated more than 217,500 MWh in 2015.[24] Of the installed distributed generation PV capacity at the end of 2015, approximately 34 percent is located at residential customer sites, 44 percent at commercial sites, and 21 percent at industrial sites.

[24] EIA. "Form EIA-826 detailed data: Solar PV estimate." Accessed April 13, 2016. www.eia.gov/electricity/data/eia826/.

Figure 23. Solar PV net metering capacity in Pennsylvania



Source: EIA. "Form EIA-826 detailed data: Net metering," (2013, 2014, 2015).

Commercial and residential energy use

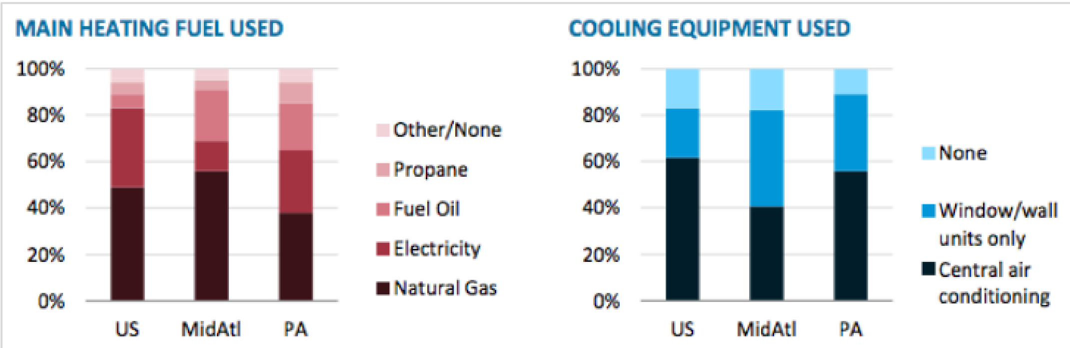
Space heating (50 percent) and cooling (3 percent) and water heating (15 percent) are responsible for a majority of electricity used in Pennsylvania homes, with the remainder used by appliances and lighting.[25] Slightly more than half of Pennsylvania households used natural gas as their primary home heating fuel in 2013, while 22 percent use electric heating, 18 percent use fuel oil, and 4 percent use liquid petroleum gases (see Figure 24).[26] Electricity is the primary energy source used to cool households, with 56 percent using central air conditioning and one-third using individual window/wall units.[27]

[25] EIA. "Household Energy Use in Pennsylvania." Accessed April 13, 2016. www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/pa.pdf.

[26] EIA, Pennsylvania: Profile Data.

[27] PA DEP, Draft 2015 Climate Change Action Plan, 10.

Figure 24. Residential heating and cooling in Pennsylvania homes



Source: Reproduced from EIA. "Household Energy Use in Pennsylvania." Note: The figures indicate the proportion of homes in Pennsylvania using the fuel as the primary source for heating and cooling.

Combining a U.S. average for commercial buildings[28] and a Pennsylvania-specific average for the residential sector,[29] approximately 20 percent of space heating and 31 percent of water heating is already electrified.[30] Beyond space conditioning and water heating, most other end-uses in residential and commercial buildings are fully electrified. The major exceptions to this are cooking in both sectors, and clothes drying to a lesser extent in the residential sector.

Industrial sector

Industrial energy use can be broken down into fossil fuel combustion, industrial processes, coal mining, and natural gas and oil system activities.

In 2013, 16.7 percent of energy consumption in the industrial sector was powered using retail electricity sales, with natural gas (35 percent), coal (22 percent), and petroleum fuels (22 percent) making up the majority of industrial energy use (see Figure 25).[31] Energy-intensive industries in the state include agriculture; mining; aluminum, steel and related heavy manufacturing; forest products; and tourism.

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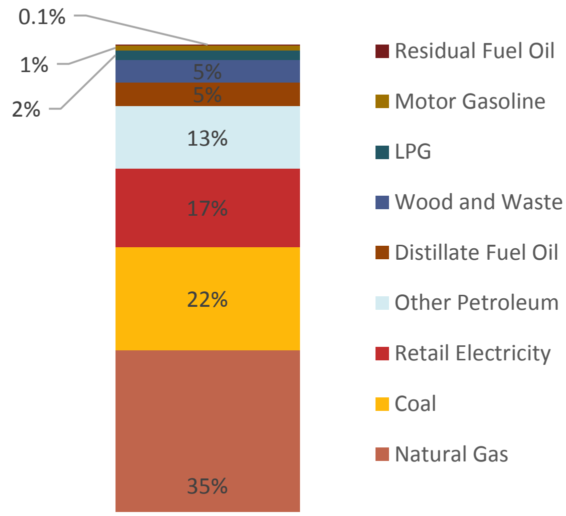
[28] EIA. "Commercial Energy Consumption Survey." Accessed April 14, 2016. www.eia.gov/consumption/commercial/.

[29] EIA. "Residential Energy Consumption Survey." Accessed April 14, 2016. www.eia.gov/consumption/residential/.

[30] The averages are calculated on a weighted basis based on the relative energy consumption of each sector.

[31] EIA. "Table CT6: Industrial Sector Energy Consumption Estimates, 1960-2013."

Figure 25. Pennsylvania industrial sector energy consumption, 2013



Source: EIA. "Table CT6: Industrial Sector Energy Consumption Estimates, 1960-2013."

According to the Statewide Evaluator Team, which conducts monitoring, verification, and assessments related to electric distribution company energy efficiency and conservation programs in Pennsylvania, the industrial sector has a technical energy savings potential of 13 percent by 2020, and 24.6 percent by 2025, relative to 2010.[32]

Transportation

The primary energy source fueling transportation needs in Pennsylvania is petroleum, which accounts for 95 percent of energy use in the transportation sector.[33] In 2013, there were 98.3 million vehicle miles traveled in Pennsylvania, ranking ninth in the United States.[34]

Pennsylvania's transportation infrastructure includes:

- 23 interstate highways totaling 1,953 miles crossing through the state, accounting for 24 percent of all vehicle traffic,[35]
- 3,874 gas stations in 2012,[36]

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[32] Statewide Evaluation Team. 2015. *Energy Efficiency Potential Study for Pennsylvania*, 49.

[33] Corbett, T, Pennsylvania State Energy Plan, 38.

[34] EIA, Pennsylvania: Profile Data.

[35] Corbett, T, Pennsylvania State Energy Plan, 49.

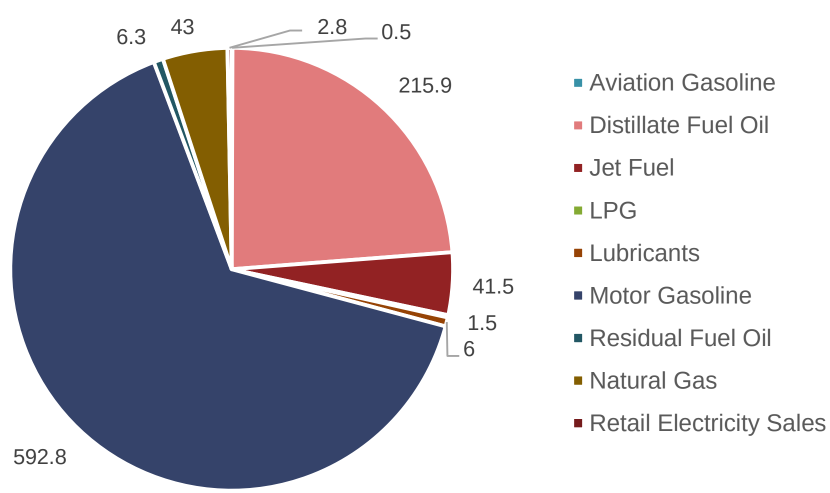
[36] EIA, Pennsylvania: Profile Data.

- Six international airports and 15 scheduled service airports in Pennsylvania, resulting in more than 20 million departing passengers and approximately 1.2 million metric tons of cargo every year,[37]
- 5,000 miles of railroads,[38] and
- A deep-water port in Philadelphia (4th largest in the United States for handling imported goods), an inland port in Pittsburgh, and a Great Lakes port in Erie.[39]

Between 2015 and 2030, energy use in Pennsylvania's transportation sector is expected to decrease by 0.52 percent each year due to increasing federal fuel economy regulations for light-duty vehicles.[40] Furthermore, the Pennsylvania Clean Vehicles Program requires that new vehicles be certified by the California Air Resources Board, the requirements of which include greenhouse gas standards in addition to other air pollutants.

As shown in Figure 26, almost all of the energy powering transportation uses in Pennsylvania are derived from petroleum, with small portions from natural gas and electricity.

Figure 26. Transportation fuels consumed in Pennsylvania, 2013 (trillion BTU)



Source: EIA. "State Energy Data System."

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[37] Corbett, T, Pennsylvania State Energy Plan, 50.

[38] Corbett, T, Pennsylvania State Energy Plan, 51.

[39] Corbett, T, Pennsylvania State Energy Plan, 51.

[40] PA DEP, Draft 2015 Climate Change Action Plan, 82.

3.2. Renewable Energy and Energy Efficiency Progress

Pennsylvania has already taken important first steps to increase its use of renewable energy and energy efficiency. While there is more work to be done, these foundational policies offer a starting point and a useful policy framework for accelerating the state's clean energy transition.

Renewable energy

In November 2004, Pennsylvania enacted the Alternative Energy Portfolio Standard (AEPS). AEPS requires each EDC and electric generation supplier to retail electric customers in Pennsylvania to supply specific amounts of electricity sourced from alternative energy each year, with an end target of 18 percent by the June 2020 – May 2021 compliance year ("CY 2021"). Specifically, in that final year, 0.5 percent must come from solar PV, 8 percent must come from Tier I sources (including the solar PV carve-out), and at least 10 percent must come from Tier II sources.

Tier I alternative energy sources include solar PV, solar thermal, wind, low-impact hydropower, geothermal electric, biomass, biologically derived methane gas (anaerobic digestion), fuel cells, and coal mine methane. Tier II alternative energy sources include waste coal, distributed generation systems, demand-side management, large-scale hydropower, municipal solid waste, generation of electricity utilizing by-products of the pulping process and wood manufacturing process, and integrated combined coal gasification technology.[41] Clearly, not all "alternative" energy technologies that are eligible Tier I or Tier II resources under the AEPS are renewable, environmentally sustainable resources. For instance, waste coal and coal mine methane qualify for the AEPS, as do facilities that may use natural gas such as fuel cells, small cogeneration and industrial blast furnaces. Likewise, pumped storage hydropower reservoirs may be charged using fossil generation resources. Pennsylvania has historically met a substantial portion of AEPS requirements with resources other than wind, water, and solar.

Energy 101: An overview of *other* energy sources

Most people are familiar with traditional sources of energy: coal, natural gas, petroleum (oil, gasoline, diesel, etc.), and nuclear as well as renewable energy sources like solar panels and wind turbines. But there are many other sources of energy that are also eligible as "alternative energy" sources in Pennsylvania. Under the Pennsylvania AEPS, each of these resources has a distinct definition. For the purpose of clarity, several of these definitions are paraphrased below:

- Biologically Derived Methane Gas: Methane (essentially, natural gas) that is produced from microorganisms breaking down biodegradable materials in the absence of oxygen and then combusted to generate electricity. This includes landfill gas as well as anaerobic digesters that use animal waste (e.g., livestock farms) or human waste (wastewater treatment plants).

[41] 73 P.S. § 1648.1-1648.8

- Biomass: Electricity produced from the combustion of plant matter or solid nonhazardous cellulosic waste material (e.g., pallets, tree trimmings, and agricultural residues).

- Coal Mine Methane: Methane (essentially, natural gas) that is found in underground coal deposits and combusted to generate energy.

- Demand-Side Management: Technologies or management practices that shift electric load from periods of high demand to low demand, including solar water heating facilities, and industrial by-products (e.g., blast furnace exhaust gas) used to generate electricity.

- Distributed Generation: Facilities of 5 MW or less that produce electricity and useful thermal energy (i.e., cogeneration or combined heat and power facilities).

- Fuel cell: An electrochemical device that converts chemical energy in a hydrogen-rich fuel directly into electricity, heat, and water without combustion. In Pennsylvania fuel cells are not required to use hydrogen sourced from renewable sources, thus fuel cells that use natural gas as a fuel are permitted to qualify for the AEPS.

- Geothermal Electric: Electricity produced using geothermal hot water or steam to drive a generator that produces electricity (i.e., not geothermal energy used for heating)

- Integrated Combined Coal Gasification: A coal plant using a gasifier to turn coal into a synthesis gas prior to combusting the fuel to generate electricity.

- Large-Scale Hydropower: Hydropower that does not meet the definition of low-impact hydropower. This includes pumped storage hydropower facilities, in which water is pumped from low elevation to a higher elevation reservoir and released to generate electricity when needed. Most often the pumping power is provided by inflexible baseload electricity generation facilities (e.g., coal or nuclear) with excess generation capability during off-peak hours.

- Low-Impact Hydropower: Hydropower that meets certification standards of the Low Impact Hydropower Institute and American Rivers, Inc., and which also does not have adverse impacts on aquatic systems, aquatic life, erosion, or cultural and historic resources.

- Municipal Solid Waste: Energy from existing waste-to-energy facilities (i.e., solid waste incinerators) that are in compliance with environmental regulations.

- Waste Coal: Previously discarded coal of low-energy value that is combusted to generate electricity in a coal plant that has certain environmental pollution control measures in place.

EDCs and electric generation suppliers comply with their AEPS requirements by retiring alternative energy credits, which equals one MWh of qualified generation. EDCs and electric generation suppliers can obtain alternative energy credits from anywhere in the PJM Interconnection region to comply with the AEPS, meaning the alternative energy does not necessarily have to be generated in Pennsylvania to be counted towards compliance.

In the most recent AEPS compliance report published in January 2016, the Pennsylvania PUC found that all EDCs complied with their CY 2014 requirements, but four electric generation suppliers did not, and were therefore required to pay alternative compliance payments for the amount of the requirement they failed to meet.[42] Tier I requirements were met primarily by wind (61 percent), landfill gas (18 percent), and wood and wood waste (14 percent). Tier II requirements were met primarily with hydro pumped storage (56 percent), waste coal (36 percent), and conventional hydro (4 percent). The solar PV requirement was met mostly with in-state resources (85 percent), whereas only 31 percent of all Tier I resources and 65 percent of Tier II resources were located in Pennsylvania.

Table 4 shows that 64.1 percent of Tier I, 4.0 percent of Tier II, and 100 percent of the solar carve-out AEPS obligations were met using wind, water, and sun (excluding pumped hydro) in 2014, or 3.2 percent of total Pennsylvania sales.

Table 4. 2015 AEPS compliance using water, wind, and solar sources

Wind, Water, or Solar?	% of 2014 Tier I
Wind	60.8%
Conventional Hydro	3.3%
Total	64.1%
Wind, Water, or Solar?	**% of 2014 Tier II**
Conventional Hydro	3.7%
DG	0.3%
Total	4.0%
Wind, Water, or Solar?	**% of 2014 Solar Carve-Out**
Solar PV	100%
Total	100%

Source: "Pennsylvania PUC. 2014 Annual Report: Alternative Energy Portfolio Standards Act of 2004.

Twenty-nine states and the District of Columbia have renewable portfolio standards (RPS), and 8 states have a renewable portfolio goal. Relative to RPS policies in other states, Pennsylvania's AEPS is not particularly ambitious in terms of bringing additional renewable energy onto the grid. Both Tier I and II obligations, with the exception of the specific requirement for solar PV, can be met using resources other than wind, water, and solar, including fossil fuels.

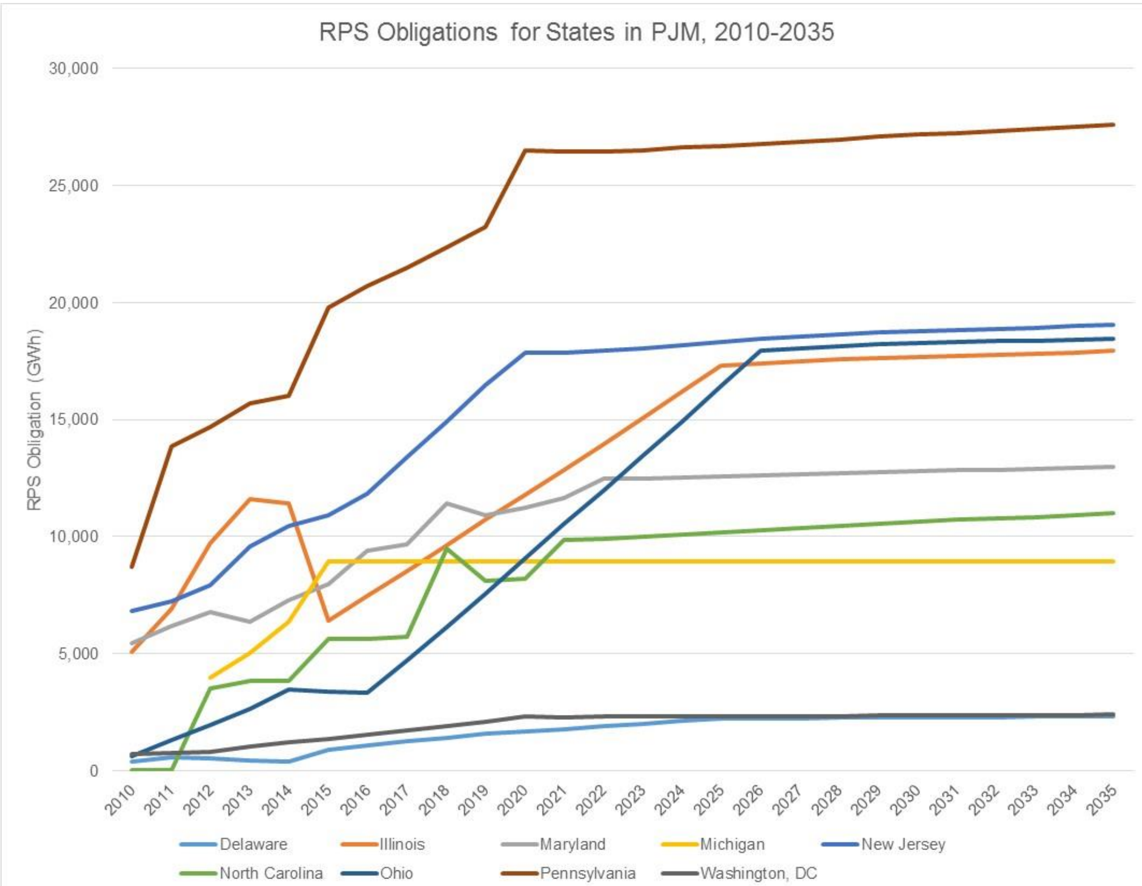
In PJM, Illinois, Maryland, Delaware, New Jersey, and the District of Columbia all have an RPS with an end target of at least 20 percent renewable energy. This is significantly higher as a percentage of state

[42] PA PUC, 2014 Annual Report.

electricity sales than the 18 percent "alternative" energy required by Pennsylvania in CY 2021. Notably, New Jersey's specific solar carve-out, requiring approximately 4.1 percent solar by 2027, has led to a solar boom in the state. More than 1,600 MW have been installed over nearly 44,000 installations in New Jersey as of February 29, 2016.[43]

Because Pennsylvania generates more total electricity than other states in PJM, its annual renewable energy generation targets on an absolute basis exceed those of other state RPS targets, as shown in Figure 27.

Figure 27. RPS/AEPS obligations for states in PJM Interconnection, 2010-2035



Source: Lawrence Berkeley National Laboratory. Compiled from "RPS Compliance Data" (February 2016) and "RPS Demand Projections" (March 2016). Note that renewable energy technologies other than wind, water, and solar and some non-renewable energy technologies are included in this figure, depending on the state-specific eligible technology criteria.

[43] New Jersey Clean Energy Program. 2016. "Renewable Energy Committee Meeting Notes." Accessed April 13, 2016. www.njcleanenergy.com/files/file/Committee%20Meeting%20Postings/renewables/Renewable%20Energy%20Committee%20Meeting%20Notes%20032416.pdf.

Distributed generation policies

Pennsylvania has enacted one of the strongest net metering policies in the nation. It has earned an "A" every year since 2007 in the annual *Freeing the Grid* report, which grades states on their distributed generation policies.[44] All investor-owned utilities are required to offer net metering for residential systems up to 50 kW, non-residential systems up to 3 MW, and microgrid and emergency systems up to 5 MW. Systems cannot exceed 200 percent of the customer's annual on-site electricity consumption. There is no aggregate capacity limit, and virtual net metering is allowed. PJM states Ohio, West Virginia, Maryland, Delaware, and New Jersey also earned an "A" for net metering.

Pennsylvania earned a "B" for its interconnection policy in *Freeing the Grid*. The requirement that customers have a redundant external disconnect switch and the applicability of the policy to only investor-owned utilities are two limitations of the existing framework. Illinois, Ohio, Virginia, and North Carolina have all enacted better interconnection policies, earning an "A," and Indiana, West Virginia, Maryland, Delaware, and New Jersey all received a "B."

Energy efficiency

Pennsylvania has enacted a number of important policies to promote energy efficiency. Most significant to the electric sector is the state's energy efficiency resource standard, the Energy Efficiency and Conservation Program, which was enacted in 2008 and implemented in 2009. The program's reduction targets apply to the seven EDCs that have at least 100,000 customers. These EDCs were required to reduce electricity consumption by 1 percent by the end of CY 2011, and 3 percent by the end of CY 2013 relative to June 2009 – May 2010 ("Phase I"). Applicable EDCs were also required to reduce peak demand by 4.5 percent by the end of CY 2013 relative to June 2007 – May 2008 peak demand.

Subsequently, the PUC extended these requirements in Phase II (CY 2014 – CY 2016)[45] and Phase III (CY 2017 – CY 2021)[46] orders, as shown in Table 5.

[44] Interstate Renewable Energy Council (IREC). "Freeing the Grid 2015." Accessed April 13, 2016. www.freeingthegrid.org.

[45] PA PUC. 2012. *Implementation Order, Docket No. M-2012-2289411;* August 2.

[46] PA PUC. 2015. *Implementation Order, Docket No. M-2014-2424864;* June 11.

Table 5. Pennsylvania utility energy efficiency resource standard, CY 2014-2021

Utility	Phase II (CY 2014 - CY 2016)		Phase III (CY 2017 - CY 2021)	
	MWh Reduction	% Reduction	MWh Reduction	% Reduction
PECO (Exelon)	1,125,851	2.90%	1,962,659	5.00%
PPL	821,072	2.10%	1,443,035	3.80%
Met-Ed (FirstEnergy)	337,753	2.30%	599,352	4.00%
West Penn (FirstEnergy)	337,533	1.60%	540,986	2.60%
Penelec (FirstEnergy)	318,813	2.20%	566,168	3.90%
Duquesne Light	276,722	2.00%	440,916	3.10%
Penn Power (FirstEnergy)	95,502	2.00%	157,371	3.30%
Total (MWh)/Average (%)	**3,313,246**	**2.16%**	**5,710,487**	**3.67%**

For Program Year 6 (June 1, 2014 – May 31, 2015), which falls in the second year of the three-year Phase II, the Statewide Evaluation Team found that the seven EDCs subject to the efficiency requirements had achieved 93 percent of the Phase II MWh/yr targets, or 2,5055,656 MWh/yr during Phase II.[47]

The technical, economic, and achievable potential for energy efficiency in Pennsylvania is outlined in Table 6 and Table 7, reproduced from Energy Efficiency Potential Study for Pennsylvania.[48] Technical potential is "the theoretical maximum amount of energy use that could be displaced by efficiency, disregarding non-engineering constraints."[49] The economic potential is the portion of the technical potential that is cost-effective to implement, and the achievable potential is the portion of the economic potential that "can realistically be saved given various market barriers" and given program administration costs.[50] The maximum achievable estimate represents a perfectly priced incentive amount, whereas the base achievable case is an estimate that assumes EDCs pay an historical incentive level of 57.5 percent of measured incremental costs for the residential sector and roughly 25 percent for the commercial and industrial sectors.[51]

[47] Statewide Evaluation Team. *Act 19 Statewide Evaluator Annual Report: Program Year 6: June 1, 2014-May 31, 2015* (March 8, 2016), 3-7. Accessed April 14, 2016. www.puc.state.pa.us/Electric/pdf/Act129/SWE_PY6-Final_Annual_Report.pdf.

[48] Statewide Evaluation Team. 2015. *Energy Efficiency Potential Study for Pennsylvania*; Tables ES-1 and ES-2.

[49] Statewide Evaluation Team, Energy Efficiency Potential Study for Pennsylvania, 17.

[50] Statewide Evaluation Team, Energy Efficiency Potential Study for Pennsylvania, 20.

[51] Statewide Evaluation Team, Energy Efficiency Potential Study for Pennsylvania, 20-21.

Table 6. Statewide summary of potential savings and costs by scenario by year

	2016	2017	2018	2019	2020	2025
Cumulative Savings Potential - MWh						
Technical	6,707,085	13,016,622	18,973,644	24,294,903	25,336,859	41,190,328
Economic	4,895,392	9,387,083	13,662,316	17,628,245	17,253,764	26,944,933
Maximum Achievable	2,761,211	5,438,518	8,133,238	10,772,462	10,983,129	19,357,092
Base Achievable	1,610,739	3,285,284	4,980,543	6,649,165	6,748,807	12,111,889
Program	1,217,554	2,480,941	3,758,994	5,015,090	5,092,433	-
Cumulative Savings Potential - % of 2010 Load						
Maximum Achievable	1.9%	3.7%	5.5%	7.3%	7.5%	13.2%
Base Achievable	1.1%	2.2%	3.4%	4.5%	4.6%	8.3%
Program	0.8%	1.7%	2.6%	3.4%	3.5%	-
Incremental Savings Potential - MWh						
Maximum Achievable	2,761,211	2,866,823	2,989,121	3,104,271	2,610,702	2,574,169
Base Achievable	1,610,739	1,725,249	1,836,917	1,943,976	1,665,279	1,794,256
Program	1,217,554	1,302,307	1,386,202	1,466,663	1,256,735	-
Incremental Savings Potential - % of 2010 Load						
Maximum Achievable	1.9%	2.0%	2.0%	2.1%	1.8%	1.8%
Base Achievable	1.1%	1.2%	1.3%	1.3%	1.1%	1.2%
Program	0.8%	0.9%	0.9%	1.0%	0.9%	-
EDC Program Costs - Million $						
Maximum Achievable	$581.8	$601.9	$619.9	$638.5	$607.0	$642.6
Base Achievable	$302.1	$316.2	$329.3	$342.6	$325.7	$361.6
Program	$228.7	$239.2	$249.1	$259.2	$246.4	n/a*

**Program potential was only estimated for five years to be consistent with a Phase III of Act 129. Program potential in 2025 would be part of Phase IV of Act 129*

Table 7. Statewide cumulative annual potential by customer sector by year

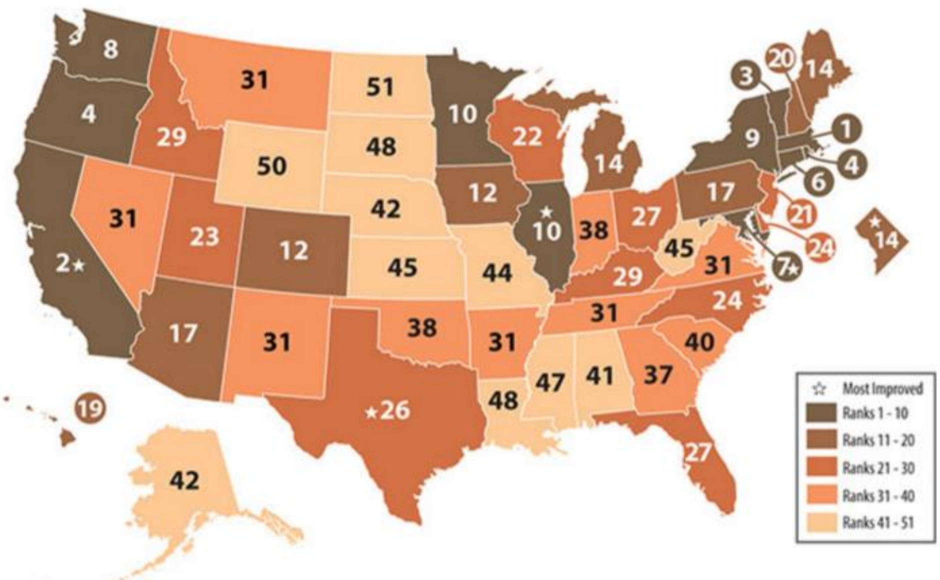
Base Achievable Potential	2016	2017	2018	2019	2020	2025
Cumulative Savings Potential - MWh						
Residential	953,810	2,005,954	3,087,372	4,149,256	3,722,120	6,587,083
Commercial	408,759	791,076	1,173,748	1,550,571	1,853,605	3,205,776
Industrial	248,169	488,254	719,423	949,338	1,173,082	2,319,030
Cumulative Savings Potential - % of 2010 Load						
Residential	0.7%	1.4%	2.1%	2.8%	2.5%	4.5%
Commercial	0.3%	0.5%	0.8%	1.1%	1.3%	2.2%
Industrial	0.2%	0.3%	0.5%	0.6%	0.8%	1.6%

Although Pennsylvania is a large energy producer and electricity generator, per-capita energy use and expenditures were in the bottom half of U.S. states in 2013 at 297 million BTU per capita per year at an average annual cost of $4,230.[52]

[52] EIA, Pennsylvania: Profile Data.

Overall, Pennsylvania ranked 17th among states on the American Council for an Energy-Efficient Economy's 2015 State Energy Efficiency Scorecard.[53] Of states in PJM, only Maryland (7th), Illinois (10th), and Michigan (14th) scored higher (see Figure 28).

Figure 28. ACEEE's 2015 State Energy Efficiency Scorecard



Source: Reproduced from ACEEE. "State Energy Efficiency Scorecard."

Building codes

Pennsylvania has adopted statewide building codes, but the current codes are somewhat dated. Currently, the 2009 International Energy Conservation Code (IECC) remains in effect for both residential and commercial buildings in Pennsylvania.[54] In comparison to Pennsylvania, 16 states have adopted more recent (i.e.,2012 or 2015) versions of the IECC residential building codes and 22 have adopted more recent commercial building codes.[55] The more recent versions of the IECC are more stringent than older versions.

[53] American Council for an Energy-Efficient Economy (ACEEE). "State Energy Efficiency Scorecard." Accessed April 13, 2016. www.aceee.org/state-policy/scorecard.

[54] Building Codes Assistance Project. "State Code Status: Pennsylvania." www.bcap-energy.org/code-status/state/pennsylvania/.

[55] PA DEP, Draft 2015 Climate Change Action Plan, 52.

4. ELECTRIFICATION OF TRANSPORTATION

The U.S. transportation sector is fueled primarily with petroleum fuels, including gasoline, diesel, and liquid petroleum. Currently in the United States, these petroleum fuels account for approximately 92 percent of the energy consumed by the transportation sector.[56] Pennsylvania's CO_2 emissions follow this pattern, with the transportation sector accounting for 24 percent of energy-related CO_2 emissions in 2013.[57] In order to meet the goal of 100 percent emission reductions by 2050, the transportation sector must be converted from traditional combustion engines to electric vehicles (EVs) powered by clean, renewable electricity. Reducing emissions from gas and other fossil fuel-powered vehicles will reduce CO_2 as well as other harmful emissions.[58]

EVs are not only vital to the reduction of transportation emissions, but they can also play a role in lowering electricity emissions. EVs can facilitate a greater concentration of renewables onto the electric grid by providing a flexible energy storage mechanism and by helping to balance electric demand. Specifically, utilizing smart grid technology, EVs can be charged during periods of low demand, or when excess renewable energy is being put onto the grid. They can deliver electricity back to the grid during peak demand in order to reduce the need for fossil fuel generation.[59,60]

Transitioning Pennsylvania's transportation sector to EVs and taking advantage of the benefits that EVs can provide to the grid will require major changes to infrastructure and consumer behavior, but careful strong policy changes can take Pennsylvania to a zero-emissions transportation system.

4.1. Transportation in Pennsylvania

Despite the benefits of transitioning to EVs, Pennsylvania's transportation sector is still heavily dependent on petroleum fuels. In 2013, the state's transportation sector used over 164 million barrels of petroleum fuels, including over 117 million barrels of motor gasoline (see Figure 29).[61] Within the transportation sector, gasoline-powered on-road vehicles contribute the most to greenhouse gas

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[56] EIA. 2016. "Monthly Energy Review - March." Table 2.5. Accessed April 13, 2016. www.eia.gov/totalenergy/data/monthly/pdf/sec2_11.pdf.

[57] EIA. 2015. "Energy-Related Carbon Dioxide Emissions at the State Level, 2000-2013." Accessed April 13, 2016. www.eia.gov/environment/emissions/state/analysis/pdf/table3.pdf.

[58] PennEnvironment Research & Policy Center. 2012. *Charging Forward: The Emergency of Electric Vehicles and Their Role in Reducing Oil Consumption*. Pages 3-4. Accessed April 13, 2016. www.pennenvironment.org/sites/environment/files/reports/Charging%20Forward-PennEnvironment.pdf.

[59] Ibid.

[60] Energy Storage Association. 2016. "Electricity Storage and Plug-In Vehicles." Accessed April 2016. www.energystorage.org/energy-storage/technology-applications/electricity-storage-and-plug-vehicles.

[61] EIA. 2016. "State Profile and Energy Estimates." Table CT7. Accessed April 13, 2016. www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/tra/use_tra_PA.html&sid=Pennsylvania.

emissions in Pennsylvania, accounting for 66 percent of emissions in 2010. On-road diesel vehicles account for 22 percent of greenhouse gas emissions (see Figure 30).[62] Over 10.5 million motor vehicles, including cars, trucks, buses, and motorcycles, contribute to these emissions throughout the Commonwealth.[63]

In Pennsylvania, conversion to EVs has yet to make significant reductions to these emissions. The National Renewable Energy Laboratory reports that only 4,540 electric or hybrid EVs were registered in Pennsylvania in 2014,[64] and only 2,300 all-electric vehicles were registered as of July 2015.[65] Charging infrastructure has also yet to take off in the state: an estimated 233 public electric charging stations with 462 charging outlets are available in Pennsylvania. By comparison, the United States in total has approximately 13,310 electric charging stations with 32,654 outlets.[66]

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[62] PA DEP. 2013. *Pennsylvania Climate Change Action Plan Update*. Page 27. Accessed April 13, 2016. www.portal.state.pa.us/portal/server.pt/document/1385625/final_climate_change_action_plan_update_pdf.

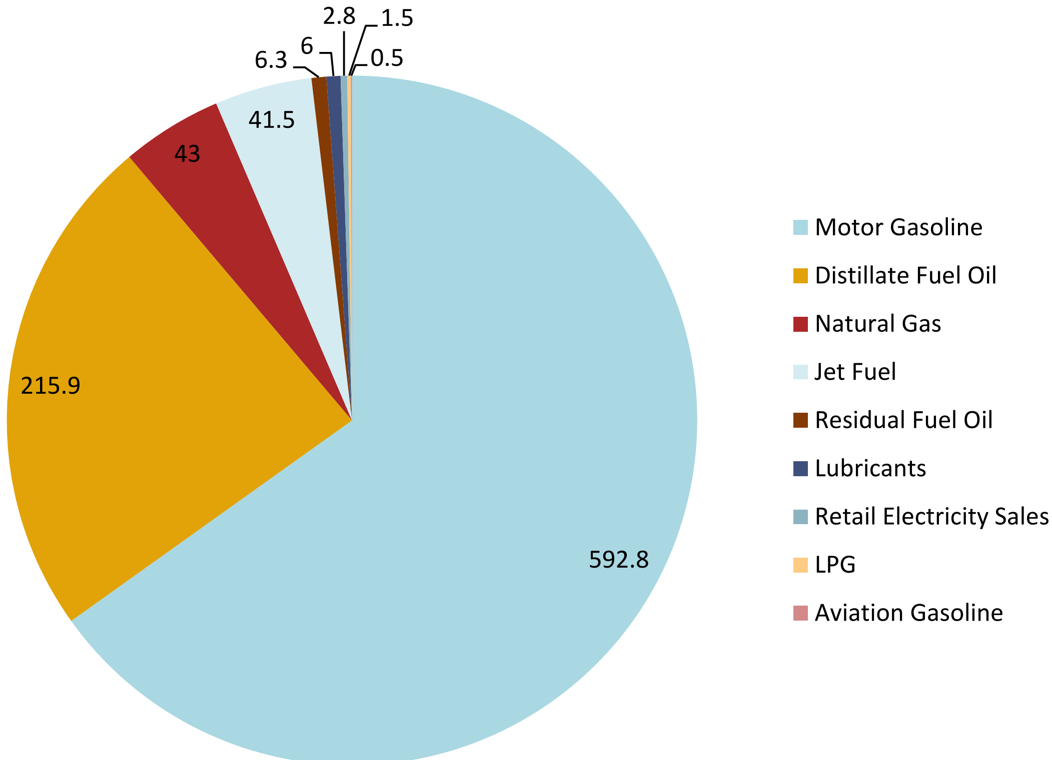
[63] U.S. Department of Transportation. 2015. "Highway Statistics 2014." Table MV-1. Accessed April 13, 2016. www.fhwa.dot.gov/policyinformation/statistics/2014/mv1.cfm.

[64] U.S. Department of Energy (US DOE). 2015. "Fact #876: June 8, 2015 Plug-In Electric Vehicle Penetration By State, 2014." Accessed April 13, 2016. www.energy.gov/eere/vehicles/fact-876-june-8-2015-plug-electric-vehicle-penetration-state-2014.

[65] PA DEP. 2016. *Electric Vehicles in Pennsylvania*. Accessed April 13, 2016. www.elibrary.dep.state.pa.us/dsweb/Get/Document-110944/0120-FS-DEP4505.pdf.

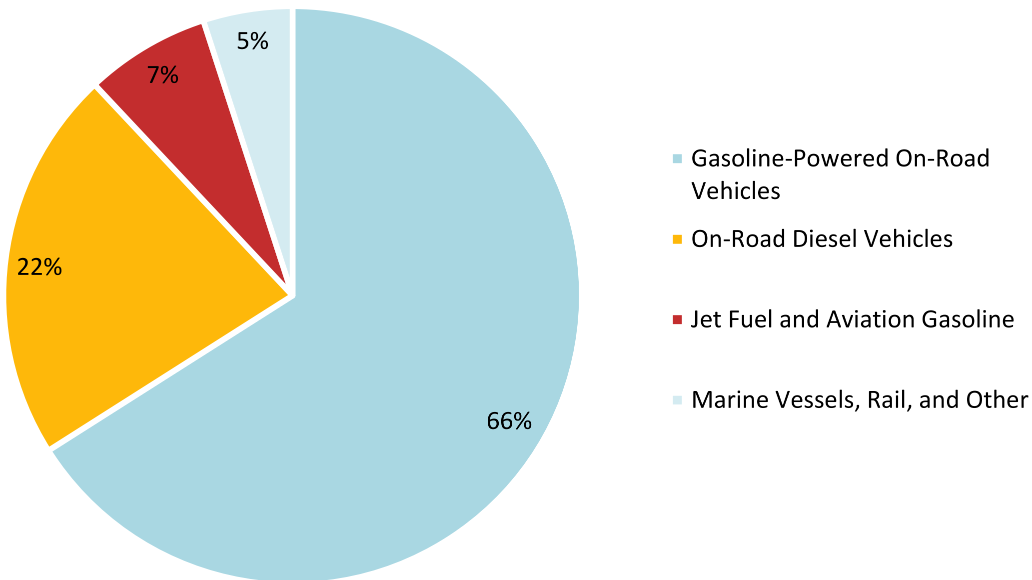
[66] Alternative Fuels Data Center. "Alternative Fueling Station Locator." Accessed April 11, 2016. www.afdc.energy.gov/locator/stations/.

Figure 29. Transportation fuels consumed in Pennsylvania in 2013, in trillion BTUs



Source: U.S. EIA. March 2016. "State Profile and Energy Estimates." Table CT7.

Figure 30. Pennsylvania greenhouse gas emissions from transportation, by end use, 2010



Source: PA DEP, 2013, "Pennsylvania Climate Change Action Plan Update."

The PA DEP has found that emissions from transportation are decreasing, declining 3.8 percent from 2000 to 2010. This trend is likely to continue due to federally mandated improvements to fuel economy.[67] In addition, according to a Commonwealth Economics study, consumer behavior, technological advancements, and public policy will also contribute to decreasing energy consumption in Pennsylvania's transportation sector.[68] EIA projects similar trends nationally as more efficient vehicles are expected to increase in market share. Energy consumed by aircraft is expected to rise nationally through 2040, as significant increases in air travel are only partially offset by improved efficiency. For both rail and marine travel, energy consumption is expected to remain relatively flat, with efficiency improvements keeping pace with a growth in demand.[69]

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[67] PA DEP, Climate Change Action Plan Update.

[68] Commonwealth Economics. 2013. *Energy in Pennsylvania: Past, Present, and Future*. Page 13. Accessed April 13, 2016. www.elibrary.dep.state.pa.us/dsweb/Get/Document-96943/Final%20PA%20Comprehensive%20Energy%20Analysis.pdf.

[69] EIA. 2015 AEO, 9-12. Accessed April 13, 2016. www.eia.gov/forecasts/aeo/pdf/0383(2015).pdf.

4.2. Pennsylvania's Electrification Efforts to Date

To date, Pennsylvania has enacted few policies to encourage the development of electric transportation. Several incentive programs are available to alternative transportation fuels broadly, but not electrification specifically. The PA DEP administers a grant program for alternative fuels known as the Alternative Fuel Grant Program. The program was established in 1992 and has a variable budget each year; the budget in 2016 is approximately $7 million.[70] Additionally, the PA DEP offers matching grants up to 50 percent under the Small Business Advantage Grant Program. These grants are available to small businesses broadly for energy-efficient or pollution prevention equipment, including auxiliary power units for trucks.[71] Financing is available from the Pennsylvania Energy Development Authority for a variety of clean, advanced energy projects.[72] Lastly, PECO Electric Company offers its customers a small incentive ($50) if they notify the utility that they have purchased an EV.[73]

The Commonwealth has also set emissions standards for passenger cars and light-duty trucks under the Pennsylvania Clean Vehicles Program. Vehicles beginning with model year 2008 that are sold or leased and titled in Pennsylvania must be certified by the California Air Resources Board or be certified for sale in all 50 states.[74]

These programs compliment a number of federal incentives available for EVs and alternative transportation technologies. A federal tax credit is available for plug-in EVs of up to 14,000 pounds. The credit is between $2,500-$7,500 depending on the battery size.[75] Two-wheeled plug-in EVs and alternative fuel infrastructure installations are also eligible for the tax credit through 2016.[76] Additional federal incentives include:

- Advanced Energy Research Project Grants
- Improved Energy Technology Loans

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70 PA DEP. 2016. "Alternative Fuels Incentive Grant Program." Accessed April 12, 2016. www.dep.pa.gov/Citizens/GrantsLoansRebates/Alternative-Fuels-Incentive-Grant/Pages/default.aspx#.VwwXGGQrJN1.

71 Alternative Fuel Data Center. 2015. "Alternative Fuel and Idle Reduction Grants." Accessed April 13, 2016. www.afdc.energy.gov/laws/5998.

72 PA DEP. 2016. "Pennsylvania Energy Development Authority." Accessed April 13, 2016. www.dep.pa.gov/Citizens/GrantsLoansRebates/Pages/PEDA.aspx#.Vw7q42QrK9a.

73 PECO Energy Company. 2016. "PECP Smart Driver Rebate." Accessed April 13, 2016. www.peco.com/Savings/ProgramsandRebates/Residential/Pages/SmartDriver.aspx.

74 Pennsylvania Department of Transportation (PA DOT). 2016. "Pennsylvania Clean Vehicles Program." Accessed April 13, 2016. www.dmv.pa.gov/VEHICLE-SERVICES/Pages/clean-vehicle.aspx#.Vw7tx2QrK9a.

75 Internal Revenue Service. 2016. "Plug-In Electric Drive Vehicle Credit (IRC 30D)." Accessed April 13, 2016. www.irs.gov/Businesses/Plug-In-Electric-Vehicle-Credit-IRC-30-and-IRC-30D.

76 Alternative Fuels Data Center. "Federal Laws and Incentives for Electricity." Accessed April 13, 2016. www.afdc.energy.gov/fuels/laws/ELEC/US.

- Low and Zero Emission Vehicle Research, Demonstration, and Deployment Funding
- Airport Zero Emission Vehicle and Infrastructure Incentives
- Alternative Fuel and Advanced Vehicle Technology Research and Demonstration Bonds[77]

Pennsylvania is also home to two Clean Cities programs—the Eastern Pennsylvania Alliance for Clean Transportation and the Pittsburgh Region Clean Cities. These programs support local actions to reduce petroleum use in transportation, including support for local infrastructure and vehicles.[78,79]

4.3. Electric Transportation Technology Options

Achieving 100 percent renewables by 2050 will require changes to all transportation modes and vehicles, and a variety of new forms of technology and infrastructure.

Light-duty vehicles

EVs are available as an option for lightweight passenger vehicles, as most auto manufacturers now offer at least one EV model.[80] However, "range anxiety," concerns about battery durability, and high costs still lead most consumers to choose more traditional gas-powered vehicles.[81] As technology improves and prices fall, EVs are expected to become more common, especially with strong policy support.[82] Plug-in hybrid vehicles also exist as a transitional vehicle option. However, in order to achieve emissions-free personal transportation, all consumers will need to adopt 100 percent EVs.

Heavy-duty vehicles

The heavier the vehicle and the longer the trips taken, the more difficult and expensive it becomes to electrify. However, technology exists to convert large trucks on the "lighter" end (less than 10,000 pounds) and certain buses to electric power.[83] Today's technology limits the range for these vehicles, but certain delivery trucks, yard hostlers (vehicles that move cargo within a single port or warehouse),

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[77] Ibid.

[78] Eastern Pennsylvania Alliance for Clean Transportation. "EP-ACT Overview." Accessed April 13, 2016. www.ep-act.org/EP-ACT-Overview.

[79] Pittsburgh Region Clean Cities. Website. Accessed April 13, 2016. www.pgh-cleancities.org/.

[80] Plug-In America. "Plug-in Vehicle Tracker." Accessed April 14, 2016. www.pluginamerica.org/vehicles.

[81] Massachusetts Institute of Technology. 2010. *Electrification of the Transportation System*. Accessed April 14, 2016. www.mitei.mit.edu/system/files/electrification-transportation-system.pdf.

[82] Randall, T. 2016. "Here's How Electric Cars Will Cause the Next Oil Crisis." *Bloomberg.com.* February 25. Accessed April 14, 2016. www.bloomberg.com/features/2016-ev-oil-crisis/.

[83] Innovation Electricity Efficiency. 2013. *Forecast of On-Road Electric Transportation in the U.S. (2010-2035)*. Page 7. Accessed April 13, 2016. www.edisonfoundation.net/iei/Documents/IEE_OnRoadElectricTransportationForecast_0413_FINAL.pdf.

military vehicles that stay on base, school and transit buses, agricultural equipment, and other non-highway vehicles are appropriate applications for full-electric vehicles that can be converted in the near term.[84,85] Heavier vehicles and those that travel long distances without opportunities to charge will require a lower conversion to emissions-free models based on significant technological advances with batteries and/or hydrogen. Emissions reductions can be accomplished in the short term with hybrid models or electrification of auxiliary power units.[86] Eventually, all vehicles will need to be transitioned to electric batteries or hydrogen fuel cells. Table 8 outlines the electrification options for different vehicle types.

Table 8. Electrification options by vehicle type

Vehicle Type	Description	Electrification Opportunities
Light-Duty Vehicle	Automobiles, Light Trucks, Motorcycles in both personal and commercial fleet usage	Electrify primary vehicle drive
Commercial Light Trucks	Trucks from 8,501-10,000 lbs. gross vehicle weight	Electrify primary vehicle drive
Transit Bus	Buses with routes inside a single metropolitan area, traversing relatively short distances with more frequent stops	Electrify primary vehicle drive
School Bus	Buses that carry students to and from educational facilities, frequent stops	Electrify primary vehicle drive
Military Use	Mix of military ground, air, and sea vehicles	Ground vehicles only: electrify primary vehicle drive
Freight Trucks	Trucks greater than 10,000 lbs. gross vehicle weight	Utilize electric umbilical for auxiliary power when idling
Air Transportation	All air carriers of passenger and cargo, as well as general aviation and small aircraft	Replace onboard mini turbine with electrical umbilical for auxiliary power when idling at gate
Domestic Shipping	Water vessels with both departure and arrival at U.S. port	Shore power: shipyard auxiliary tether to prevent idling in domestic oceanliners
International Shipping	Water borne vessels with either a departure or an arrival at a U.S. port, but not both	Shore power: shipyard auxiliary tether to prevent idling in international oceanliners
Freight Rail	Locomotive drawn freight railroad cars	Range and weight requirements prohibitive in the near term
Intercity Bus	Buses with routes between metropolitan areas, traversing mostly highways with infrequent stops	Electric options available with infrastructure upgrades; Range and weight may be prohibitive in the near term

84 Ibid.

85 Union of Concerned Scientists. 2012. *Truck Electrification: Cutting Oil Consumption & Reducing Pollution*. Accessed April 14, 2016. www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_vehicles/Truck-Electrification-Cutting-Oil-Consumption-and-Reducing-Pollution.pdf.

86 Massachusetts Institute of Technology, *Electrification of the Transportation System.*

Vehicle Type	Description	Electrification Opportunities
Intercity Rail	Trains with routes between metropolitan areas, traversing relatively long distances with infrequent stops	Many already electrified; electric options available
Transit Rail	Trains with routes inside a single metropolitan area, traversing relatively short distances with more frequent stops	Many already electrified; electric options available
Commuter Rail	Trains with routes to and from a metropolitan area, traversing moderate distances with somewhat frequent stops	Many already electrified; electric options available
Recreational Boats	Personal boats and watercraft	Electric auxiliary options while idling, docked

Source: Adopted from Innovation Electricity Efficiency. April 2013. "Forecast of On-Road Electric Transportation in the U.S. (2010-2035)." 7.

Marine and air travel

Similar to heavy-duty vehicles, technology is not yet available to electrify jets and boats. The energy required to transport a heavy boat overseas or to fly a plane even relatively short distances is too great for existing battery technology. However, in the short term, planes and boats can switch auxiliary equipment to electricity rather than using petroleum fuels for all energy needs. For example, planes typically use jet fuel for power and lighting while the plane is idling at the gate, but could instead connect to the terminal's electric supply.[87] These transportation options will eventually need to be transitioned to hydrogen fuel cell versions in order to eliminate associated emissions.[88]

Rail

Much of Pennsylvania's regional rail system is already run on electricity.[89] All rail systems must be converted to electric in order to reach zero emissions. Given that national and regional rail networks are beyond the jurisdiction of Pennsylvania, the state will need to coordinate with other states and with the Federal government in order to make the necessary improvements to the rail system.

Charging infrastructure

As more vehicles are converted to electric, charging infrastructure will need to expand throughout the state. Many vehicles can be recharged at home or at primary parking facilities, but charging

[87] Innovation Electricity Efficiency. *Forecast of On-Road Electric Transportation*, 7.

[88] Jacobson et al, 100% clean and renewable, 8.

[89] PA DOT. 2015. *2015 Pennsylvania State Rail Plan*. Chapter 2, 13. Accessed April 21, 2016. www.planthekeystone.com/PDF/StateRailPlan/Chapter%202%20-%20The%20States%20Existing%20Rail%20System_website.pdf.

infrastructure will also be needed in public parking areas (including rest stops, restaurants, shopping centers, places of employment, etc.) in order to enable the growth in vehicle electrification.

Charging equipment is classified by how quickly it can charge a battery. The charging time varies depending on the size and type of the battery. AC Level 1 charging can be accomplished through the kind of 120-volt outlet found in almost all drivers' homes. Level 1 charging can meet the average family's daily needs. It will charge a car for 40 miles of driving in about 8 hours, or anywhere between 2-5 miles per hour of charging. AC Level 2 charging requires 240 volt or 208 volt electric service and can provide for 10-20 miles of driving with just 1 hour of charging. Level 2 is used for most public charging infrastructure, and is preferred by many residential customer who desire more flexibility and faster charging.[90] Most homeowners would need to upgrade a garage outlet if they wish to use Level 2 charging. Installation of this type of outlet requires the services of an electrician and can be costly.[91]

Direct-current (DC) or Level 3 charging can provide even faster charging—between 50-70 miles for just 20 minutes of charging.[92] Such stations are useful for EV owners traveling longer distances at restaurants, malls, rest stops, etc. Level 3 charging requires a 480-volt source, which is not technically feasible for an average residential neighborhood.[93]

Behavior changes

Though technology solutions will eliminate most emissions, behavioral changes may also need to occur in order to reach 100 percent emissions reductions. Walking, bicycling, carpooling, and use of public transit will decrease the number of vehicle miles traveled that need to be converted to electric. Encouraging such behavioral changes will require changes to land use and city planning.[94]

4.4. Targets for Electric Transportation

Pennsylvania's progress toward transportation electrification has been minimal to date. Realizing 100 percent emissions will require converting almost the entire fleet of vehicles, boats, planes, and trains to electric over the next 30 years.

[90] Alternative Fuels Data Center. "Developing Infrastructure to Charge Plug-In Electric Vehicles." Accessed April 15, 2016. www.afdc.energy.gov/fuels/electricity_infrastructure.html.

[91] Electrification Coalition. 2009. *Electrification Roadmap: Revolutionizing Transportation and Achieving Energy Security*. Page 150. Accessed April 13, 2016. www.electrificationcoalition.org/sites/default/files/SAF_1213_EC-Roadmap_v12_Online.pdf.

[92] Alternative Fuels Data Center, Developing Infrastructure.

[93] Cunningham, W. 2013. "Slow, fast, and faster: Where to charge electric cars." *CNET.com.* October 1. Accessed April 21, 2016. www.cnet.com/roadshow/news/slow-fast-and-faster-where-to-charge-electric-cars/.

[94] Drexel University. 2015. *Options for Achieving Deep Reductions in Carbon Emissions in Philadelphia by 2050*. Accessed April 14, 2016. www.drexel.edu/~/media/Files/now/pdfs/Reducing%20GHG%20in%20Philadelphia.ashx?la=en.

In this study we separate the targets for transitioning the transportation sector to electricity into three separate goals: light-duty vehicles, heavy-duty vehicles, and aviation and marine travel.

Light-duty vehicles

In order to set targets for converting light-duty vehicles to electric, we relied on two recent studies that aimed to reduce emissions over a period of several decades. A 2015 study by the U.S. Federal Highway Administration describes a scenario in which states convert 33 percent of light-duty vehicles to electric by 2030.[95] Beyond 2030, a study by the Electrification Coalition, designed a roadmap to achieve 75 percent EVs nationally by 2040.[96] Based on an average vehicle lifetime of 11.5 years,[97] we find these long-term targets to be reasonable, assuming adequate incentives are created to encourage a significant portion of new vehicles purchased to be electric. We also find them to be necessary in order to achieve 100 percent by 2050.

In setting the near-term goal, we assume that approximately 20 percent of the vehicles on the road will be replaced between now and 2020, and that approximately 20 percent of those new vehicles purchased will be electric if incentives are set such that EVs are competitive with traditional vehicle models. Thus, the targets set for light-duty vehicles are as follows:

- 4 percent EVs by 2020;
- 33 percent EVs by 2030;
- 75 percent EVs by 2040;
- 100 percent EVs by 2050

Other vehicles

In order to set targets for converting other transportation modes and vehicles to electric options, we relied on the model developed by the 2015 Jacobson et al. report which created a pathway to 100 percent renewables by 2050 for the entire United States.[98]

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[95] U.S. Federal Highway Administration. 2015. "Feasibility and Implications of Electric Vehicle (EV) Deployment and Infrastructure Development, Scenario 8." Available at: www.fhwa.dot.gov/environment/climate_change/mitigation/publications/ev_deployment/es.cfm. See also Stanton, L. et al. "The RGGI Opportunity 2.0." March 4, 2016. Accessed April 21, 2016. http://www.synapse-energy.com/sites/default/files/RGGI_Opportunity_2.0.pdf.

[96] Electrification Coalition, Electrification Roadmap.

[97] Oak Ridge National Laboratory (ORNL). "Transportation Energy Data Book." Table 3-10. Accessed April 12, 2016. www.cta.ornl.gov/data/chapter3.shtml.

[98] Jacobson et al, 100% Clean and Renewable.

4.5. Policy Pathways

Even without major policy changes, electric cars are expected to increase in market share in the near future. Advancements in battery technology and decreasing costs are making EVs more competitive with fossil fuel-powered vehicles.[99]

Because air, rail, and some marine travel generally crosses state borders, Pennsylvania will need to work with the Federal government and other states to make the changes necessary to implement equipment efficiency and fuel use regulations that are set at the national level. However, there are many policy options available to state legislators and regulators to advance transportation electrification throughout Pennsylvania.

In order to achieve the targets for electric transportation, policymakers and regulators will need to work with stakeholders to determine a suite of policies that work best for the state. Those policies should include:

- Incentive programs designed to meet the needs of different consumers, including individuals, businesses, large fleets, and to support both EVs and charging equipment;
- Taxes to raise funds for incentive programs;
- Specific vehicle goals or mandates to set expectations for manufacturers and consumers;
- Setting requirements for installing charging infrastructure;
- Funding and programs to support alternative forms of transportation, especially for low-income communities;
- Regulatory changes needed to accommodate the growing number of EVs and charging stations.

Financial incentives

Financial incentives are the most direct way of encouraging purchases of EVs. With the average light-duty lifespan increasing each year,[100] providing a robust incentive program as early as possible will be crucial to boosting the adoption of EVs. Several forms of financial incentives can be used, including:

Rebates. As seen with the success of the "Cash for Clunkers" program, upfront cash rebates are the fastest, easiest way to motivate customers to purchase EVs.[101] Such programs require a dedicated

[99] Randall, T. 2016. "Here's How Electric Cars Will Cause the Next Oil Crisis." *Bloomberg L.P.* February 25. Accessed April 14, 2016. www.bloomberg.com/features/2016-ev-oil-crisis/.

[100] ORNL, Transportation Energy Data Book.

[101] Electrification Coalition, Electrification Roadmap.

source of funds that may be less politically palatable, but rebates are easy to understand and a proven method of incentivizing the adoption of new technologies.

Tax credits. Tax credits may be more politically feasible and most consumers are generally familiar with how to use them. Providing tax credits does not require a separate, dedicated fund as required with a direct rebate program. However, depending on the program design, some consumers may not have the tax appetite to take advantage of tax credits, and consumers are more motivated by immediate, upfront rebates.

Tax and fee exemptions. Exempting vehicles or charging stations from sales or property taxes, or other registration fees provides another politically palatable financial motivation for consumers. Other forms of incentives are typically more likely than tax exemptions to motivate EV purchases because consumers may not fully appreciate how much sales or property taxes may cost them.

Grants. Similar to rebates, grants can be a strong motivator for purchases of EVs or charging equipment. Grants are typically reserved for larger cash awards and may require more administration to review applications and manage awards as compared to rebates. Grants are a good option to incentivize large fleets to convert to electric, or to incentivize a large business or employer to install charging stations in its parking lots across the state, for example. Grants can also be used for research and development to facilitate technological advancements.

Loans. Zero- or low-interest loans can be used to motivate fleet conversions or other large investments in infrastructure or even vehicle or battery manufacturing. Low-interest loans are often available for vehicle purchases for consumers with good credit ratings, but the state could offer loan programs for low-income consumers or other consumers that are not eligible for commercial loan products.

No matter which incentive options are chosen, incentives for vehicles must be set such that EVs are cost-competitive with their traditional alternatives. Incentives that are set high initially and decline over time will encourage early adoption and may encourage consumers to trade in their gasoline vehicles sooner than they may have planned.[102] Different incentive options will need to be considered for individuals, fleets, charging equipment, and manufacturers.

Specifically, businesses or government agencies with large vehicle fleets can be good candidates for early adoption of EVs. Businesses' and agencies' large fleets can take advantage of economies of scale, realize significant savings in fuel costs, and influence other businesses to install charging equipment.[103] Additionally, for businesses such as utilities that operate heavy, idling vehicles, EVs will decrease employee exposure to emissions, toxins, and excessive noise, which will improve worker safety and

[102] Electrification Coalition, Electrification Roadmap.

[103] PennEnvironment Research & Policy Center, Charging Forward, 17.

customer satisfaction.[104] Vehicle manufacturers can be influenced by the needs of large fleets, as the amount of vehicles purchased directly from such fleets influence manufacturing production schedules. Such influence can be used to motivate manufacturers to prioritize EV advancements and production.[105] Early incentive programs should target large fleets with grants or loans, and can be accompanied with education and outreach programs to ensure a smooth transition to the new technologies.

Separate incentive programs can be designed to encourage the installation of charging equipment or to assist homeowners in upgrading their electric outlets. Incentive designs should take into account the current costs of charging equipment or the typical cost of a home upgrade.

Convenience incentives

In addition to the above incentives, many local jurisdictions and states offer "convenience" incentives to encourage early adopters of EVs. This can include close or free parking spaces for EVs, or special access to High Occupancy Vehicle (HOV) lanes.[106] These types of programs are only effective in the early years of a transition to EVs, as a higher penetration of EVs makes them unsustainable. Separately, as described further below, initiatives or incentives that increase the availability of EV charging infrastructure can also constitute a type of "convenience incentive" for prospective EV adopters.

Taxes

The most direct way to discourage the use of gasoline or other petroleum fuels and to encourage a transition to electric or more efficient vehicles is to increase gas taxes. The tax revenue can be used to fund the incentive programs described above, and may also boost innovation of electric alternatives for larger vehicles. While sometimes politically unsavory, a gas tax is a transparent and effective tool for reducing petroleum use.[107]

Vehicle standards and requirements

Pennsylvania and many state and federal laws already encourage increased transportation efficiency by requiring improved fuel economy standards or emissions reductions.[108,109] Accelerating efficiency and emissions requirements with goals set well out into the future will encourage manufacturers to move

[104] Edison Electric Institute (EEI). 2014. "Transportation Electrification: Utility Fleets Leading the Charge." 4. Accessed April 15, 2016. www.eei.org/issuesandpolicy/electrictransportation/FleetVehicles/Documents/EEI_UtilityFleetsLeadingTheCharge.pdf

[105] EEI, Transportation Electrification, 39.

[106] PennEnvironment Research & Policy Center, Charging Forward, 18.

[107] Electrification Coalition, Electrification Roadmap, 49, 133.

[108] PA DOT, Pennsylvania Clean Vehicles Program.

[109] National Highway Traffic and Safety Administration. "CAFE – Fuel Economy." Accessed April 14, 2016. www.nhtsa.gov/fuel-economy.

toward hybrid and all-electric vehicles, and at a certain point, the requirements will make gasoline vehicles obsolete.

Certain governments have also set specific goals for EV sales. Eight states, including California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont, have signed on to an action plan to put 3.3 million EVs on the road by 2025.[110] These eight states have also joined several European Countries and Quebec in becoming members of the International Zero-Emission Vehicle Alliance, which has a goal of requiring all new sales of passenger vehicles to be zero-emission vehicles by 2050.[111]

Another option is to ban gasoline or petroleum-fueled vehicles outright, as has been proposed in the Netherlands and Norway.[112,113] As with gas taxes, such mandates can be politically unpopular, but setting a mandate for vehicle efficiency or banning fuel sources by a certain date is a method of guaranteeing that the goals set in place will be reached. Paired with incentives, such mandates can set long-term expectations for industries and set up businesses for a successful transition.

Expanding charging infrastructure

Incentives may encourage the development of charging infrastructure, and the growing demand for infrastructure may also cause a natural expansion of chargers in order to meet demand. However, other policies may need to be implemented to ease consumers' concerns regarding the availability of chargers in the early years of the EV transition. For example, local governments and businesses can be required to include chargers as part of any new parking infrastructure. Businesses or universities of a certain size might be required to provide chargers for employees, or hotels may be required to install a certain number of chargers for overnight guests. In addition, public charging equipment should have credit card payment options rather than only prepaid charge card options to increase the accessibility of charging stations. As EVs become more prevalent, businesses will want to install chargers in order to attract consumers, but early installation of charging infrastructure will make for an easier transition for consumers.[114]

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[110] Hartman, K. 2015. "State Efforts to Promote Hybrid and Electric Vehicles." National Conference of State Legislatures. December 3. Accessed April 14, 2016. www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx.

[111] International Zero-Emissions Vehicle Alliance. 2015. "International ZEV Alliance Announcement." December 3. Accessed April 14, 2016. www.zevalliance.org/content/cop21-2050-announcement.

[112] Glon, R. 2016. "Dutch Politicians Want to Make Gasoline and Diesel-Powered Cars Illegal in 2025." *Digital Trends.* March 31. Accessed April 14, 2016. www.digitaltrends.com/cars/holland-wants-to-ban-gas-cars-by-2025-news-report/.

[113] Morris, C. 2016. "Will Norway ban gas & diesel cars by 2025?" *Renewables International.* March 20. Accessed April 14, 2016. www.renewablesinternational.net/will-norway-ban-gas-diesel-cars-by-2025/150/537/94287/.

[114] Electrification Coalition, Electrification Roadmap, 142-143.

Encouraging transportation alternatives

The costs of converting to 100 percent electric transportation can be reduced through behavior changes that decrease the number of vehicle miles traveled. Education and outreach as well as careful city planning can encourage consumers to take public transit, carpool, bicycle, walk, or telecommute in order to reduce the need for other forms of transportation. Policy options for encouraging these behaviors include:

- Increasing the costs of vehicle ownership through taxes or fees—this shift can place more pressure on low-income communities, so local planners need to ensure that public transportation, carpooling services, and sidewalks are available to these communities;
- Increasing funds for public transit and safe biking and walking infrastructure, including bike paths, bike lanes, greenways, pedestrian bridges, crosswalks, etc.; and[115]
- Leading by example by allowing state employees to telecommute or by providing carpooling or car-sharing services and encouraging other businesses to do the same.

Regulatory changes

A number of regulatory changes may need to be considered in order to accommodate a rising number of EVs and associated infrastructure.

Utility regulations

As the number of EVs increases, more electricity will be consumed. In order to keep emissions from rising, it is crucial to move electricity production to 100 percent renewables as discussed throughout this report. In addition, alternative rate designs will be needed in order to encourage EV owners to charge their vehicles during times of day when electricity is otherwise not in high demand, i.e., during off-peak hours. This is accomplished with time-of-use electricity rates, which charge higher amounts during hours of the day where electricity is the most in demand, typically mid-morning and late afternoon.[116,117] Utilities and regulators may need to experiment with different rate structures and designs in order to find a system that works for consumers and manages electricity demand.

To allow customers to take control of their EV charging schedules and electricity bills, utilities will need to adopt smart grid technologies and infrastructure. Smart grid technologies allow communication between consumers and utilities. This includes sharing information regarding how and when electricity is being consumed, and even which appliances are consuming electricity at different points throughout the day. Having this information allows consumers to make better choices about when to charge their

[115] Jacobson et al, 100% clean and renewable.

[116] Jacobson et al, 100% clean and renewable.

[117] Electrification Coalition, Electrification Roadmap, 118.

EVs or when to use appliances in order to reduce electricity costs and avoid stressing the grid.[118] In addition, smart grid technology can also allow for EVs to be used as energy storage. This can be done by charging EVs during periods of low demand, or when excess renewable energy is being put onto the grid, and actually pulling electricity back to the grid during peak demand to reduce the need for fossil fuel generation.[119,120]

Installing the equipment and software necessary to share this data will be costly, and regulators will need to determine how these costs will be recovered. Many of these investments will need to take place in order to adapt to an evolving electricity resource portfolio, so comprehensive planning is necessary. In addition, as charging infrastructure becomes more prevalent in public places, regulations regarding the price of electricity and ownership of public charging infrastructure may need to be revised.[121] Regulators and policymakers will need to be prepared to deal with these regulatory issues as they arise. These policy decisions should incorporate the benefits of smart grid upgrades and EVs such as grid stability and avoided emissions, which can help to justify the upfront costs of infrastructure investments.

Building codes

As more consumers own EVs, Level 2 or DC charging equipment should become standard in homes, multi-family buildings, and businesses. Amending building codes to require appropriate outlets on building exteriors or garages will decrease costs for consumers. Building codes can also be amended to require upgrades when any major renovations take place.[122]

Permitting

Construction of charging equipment or upgrading outlets in homes or businesses will require electric and/or construction permits depending on the size of the project and local jurisdictions' rules. The state can require streamlined or expedited permitting for such projects, using standard forms and requirements to ease the process for consumers.[123] In addition, trainings and workshops may be provided for local inspectors and permitting offices to ensure that local officials are comfortable reviewing applications and inspecting installations.

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[118] Electrification Coalition, Electrification Roadmap, 104.

[119] PennEnvironment Research & Policy Center. 2012. "Charging Forward: The Emergency of Electric Vehicles and Their Role in Reducing Oil Consumption." 3-4. Accessed April 13, 2016. http://www.pennenvironment.org/sites/environment/files/reports/Charging%20Forward-PennEnvironment.pdf

[120] Energy Storage Association, Electricity Storage and Plug-In Vehicles.

[121] MIT, Electrification of the Transportation System.

[122] Electrification Coalition, Electrification Roadmap, 117.

[123] Electrification Coalition, Electrification Roadmap, 142.

5. ELECTRIFICATION OF HEATING

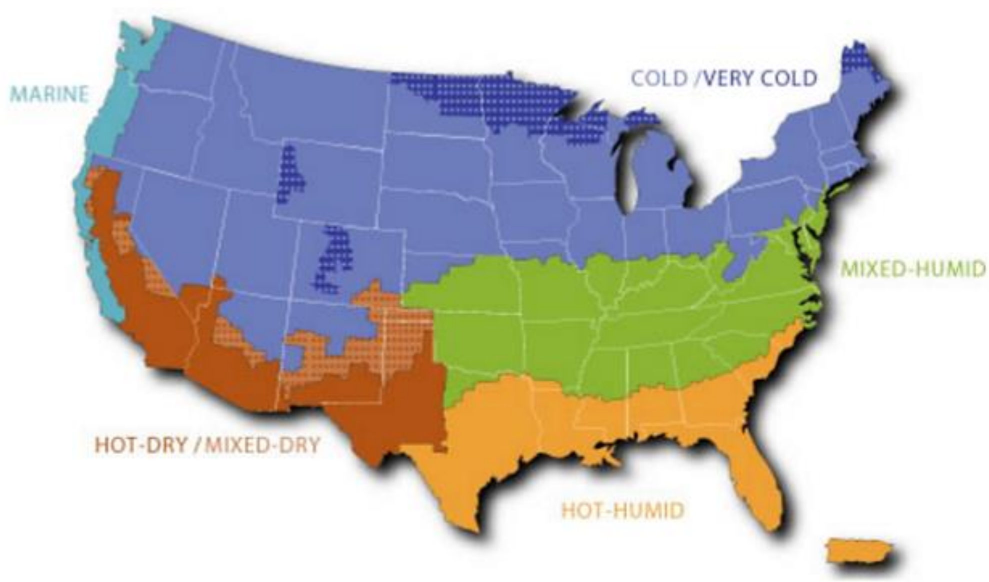
The electrification of energy end uses plays a critical role in the transition to 100 percent wind-, water-, and solar-based energy consumption in Pennsylvania by 2050. Two end uses in particular—space heating and water heating—are key to address in the residential and commercial sectors, as they account for a significant portion of total energy use. Electrification of industrial end uses of energy is more idiosyncratic: Some heat-intensive processes pose a particularly difficult challenge for electrification, as existing technologies are less adept at immediately replacing fossil fuel use.

Space heating and water heating are often met with on-site consumption of natural gas, and to a lesser extent, fuel oil or propane. While both of these end uses can be met through alternatives that use electricity, the favorable economics of fossil fuel commodity prices and relative combustion efficiencies have disincentivized more widespread electrification among these end uses in the past. Similarly, other examples of non-electrified energy end-uses in the residential and commercial sectors, such as natural gas-based chillers or clothes dryers, can be electrified using existing technologies commercially available today.

5.1. Residential and Commercial Space Heating

Space heating is a substantial energy end use in Pennsylvania, which has a colder-than-average climate relative to the rest of the country (Figure 31).

Figure 31. EIA's "Building America" climate regions

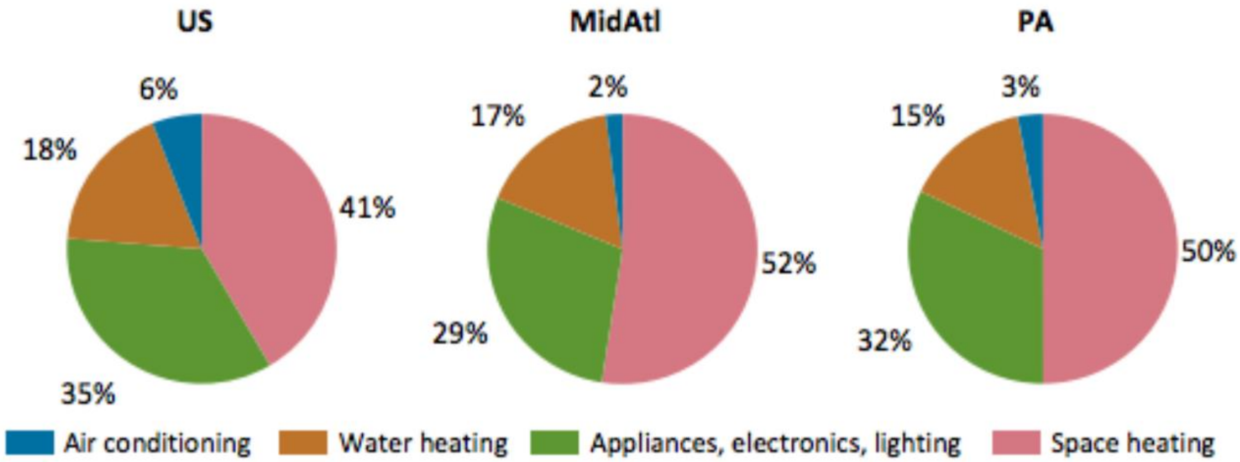


Source: Reproduced from EIA. "Residential Energy Consumption Survey (RECS): Maps" using RECS 2009 data.

Residential sector

Space heating accounts for half of all home energy consumption in Pennsylvania, a higher proportion than the national average (Figure 32).

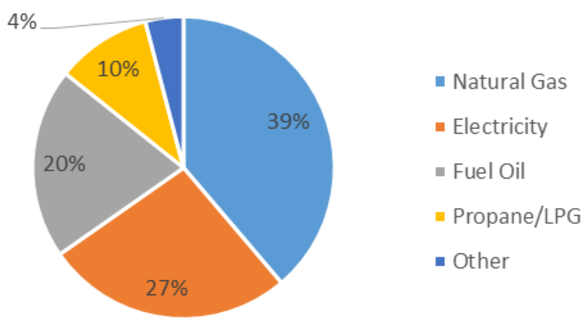
Figure 32. Residential energy consumption by end use, 2009



Source: Reproduced from EIA. "Household Energy Use in Pennsylvania." Note: The figures indicate the proportion of homes in Pennsylvania using the fuel as the primary source for heating and cooling.

As illustrated in Figure 33, only 27 percent of homes in the Northeast region that includes Pennsylvania have electric heating, with a majority of homes directly using fossil fuel-based heating from natural gas (39 percent), fuel oil (20 percent), or propane (10 percent). Wood and coal-burning stoves are among space heating technologies that are less common but still in use in the Commonwealth.

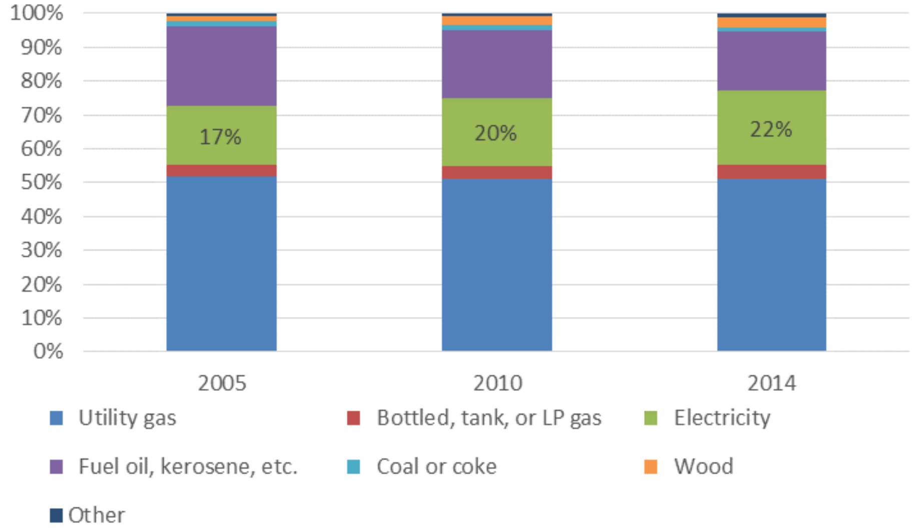
Figure 33. Fuel source of space heating equipment in Pennsylvania homes, 2009



Source: EIA. "Table HC6.8 Space Heating in U.S. Homes in Northeast Region, Divisions, and States, 2009." Residential Energy Consumption Survey.

Data from the U.S. Census Bureau's American Community Survey shows a slight increase over the past decade in the share of energy for home heating coming from electricity (Figure 34). Natural gas consumption for space heating held constant, with just over half (51 percent) of residential space heating energy use in 2014.

Figure 34. Residential space heating energy sources in Pennsylvania, 2005-2014

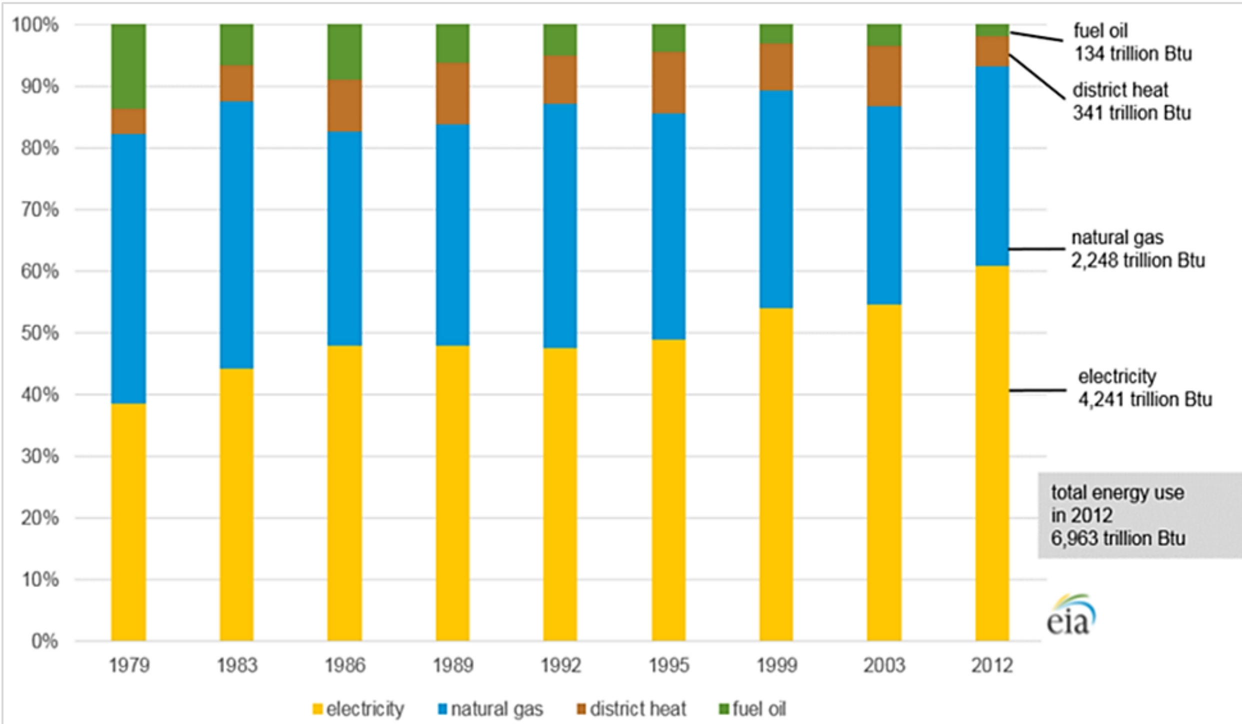


Source: U.S. Census Bureau. American Community Survey. 2014.

Commercial sector

The commercial sector has become increasing electrified over time in the United States with 61 percent of building energy consumption attributable to electricity use (Figure 35).

Figure 35. Commercial building energy consumption by source, United States, 2012

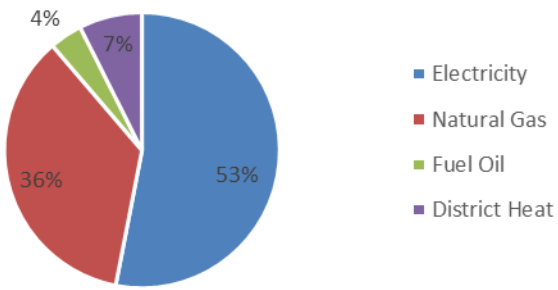


Source: Reproduced from EIA. "2012 Commercial Building Energy Consumption Survey: Energy Usage Summary." Accessed April 27, 2016.

As shown in Figure 36, in the Mid-Atlantic region (Pennsylvania, New York, and New Jersey), 53 percent of commercial building energy use in 2012 was electrified, with natural gas (36 percent), district heat (7 percent), and fuel oil (4 percent) making up the balance. In comparison to the national averages shown in Figure 5, the commercial sector in Mid-Atlantic states is less electrified and uses more natural gas, district heat, and fuel oil as a proportion of total energy consumption.

District heating involves a centralized plant that generates or captures heat and distributes it via pressurized hot water or steam through insulated pipes to the end user. Although district heating typically uses cogeneration technology to capture heat produced from burning fossil fuels, it can alternatively utilize renewable resources like geothermal, central solar heating, or electric heat pumps using electricity generated from wind, water, and solar.

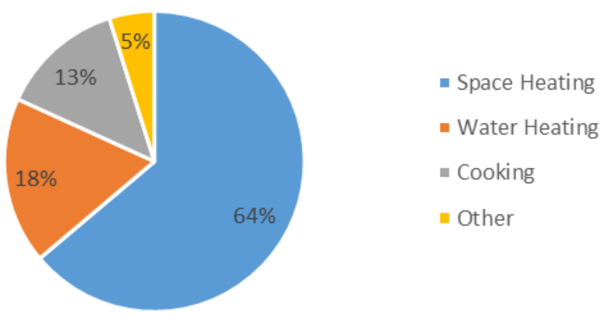
Figure 36. Commercial building total energy consumption by source in Mid-Atlantic states, 2012



Source: EIA. "Table 1. Total Energy Consumption by Energy Source, 2012." Commercial Building Energy Consumption Survey.

As highlighted in Figure 37, 95 percent of natural gas used in commercial buildings in the Mid-Atlantic states is for three specific services: space heating (64 percent), water heating (18 percent), and cooking (13 percent).

Figure 37. Commercial building natural gas consumption by source in Mid-Atlantic states, 2012

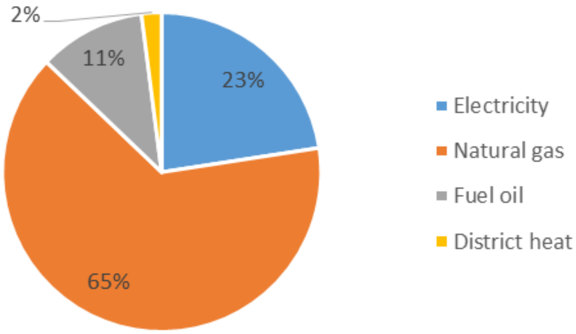


Source: EIA. "Table 7. Natural Gas Consumption by End Use, 2012." Commercial Building Energy Consumption Survey.

As depicted in Figure 38, only 23 percent of commercial buildings rely on electric heating as their primary space heating energy source in Mid-Atlantic states.[124] Nearly two-thirds (65 percent) of commercial buildings use natural gas as their primary heating source, with the balance coming from fuel oil (11 percent) and district heat (2 percent).

[124] Data specific to Pennsylvania is not provided in the Commercial Building Energy Consumption Survey, so Mid-Atlantic regional data are used.

Figure 38. Commercial building primary space heating energy sources in Mid-Atlantic states, 2012



Source: EIA. "Table B4. Census Region and Division, Number of Buildings, 2012." Commercial Buildings Energy Consumption Survey.

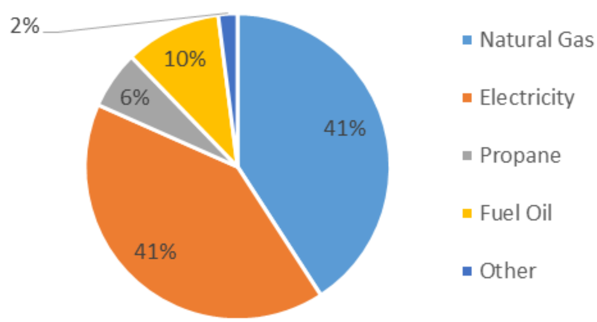
5.2. Residential and Commercial Water Heating

Water heating is another ripe opportunity for aggressive electrification targets due to readily available substitute technologies.

Residential sector

On average, water heating accounts for 15 percent of household energy consumption in Pennsylvania.[125] Electric (41 percent) and natural gas (41 percent) water heating are the primary fuel sources for most home water heating in Pennsylvania, although fuel oil (10 percent) and propane (6 percent) water heating are also used (Figure 39).

Figure 39. Residential water heating in Pennsylvania, 2009



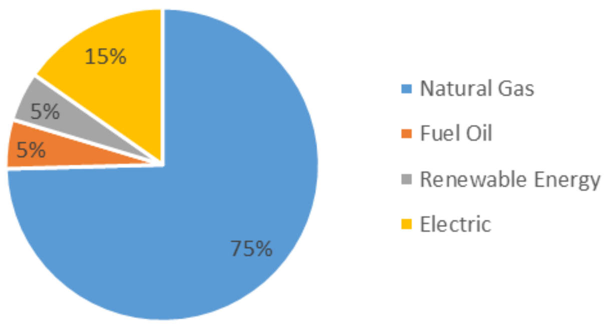
Source: EIA. "Table HC8.8 Water Heating in U.S. Homes in Northeast Region, Divisions, and States, 2009."

[125] EIA, Household Energy Use in Pennsylvania.

Commercial sector

Natural gas (75 percent) remains the primary fuel source for water heating in commercial buildings in the United States (Figure 40).[126] Fifteen percent of water heating load has been electrified, with fuel oil (5 percent) and renewable energy (2 percent) less prevalent.

Figure 40. Commercial building water heating energy consumption in the United States, 2010



Source: US DOE. "3.1.4 2010 Commercial Energy End-Use Splits, by Fuel Type (Quadrillion Btu)." Building Energy Data Book, 2010.

5.3. Other Residential and Commercial Electrification

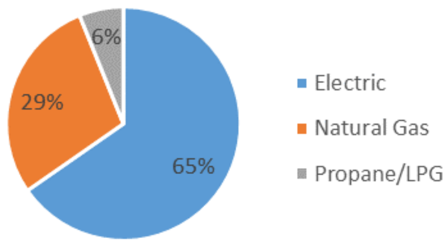
While space heating and water heating will involve the largest shifts in residential and commercial electrification, they are not the only building end uses that will have to be electrified to get to 100 percent renewable energy by 2050. Several miscellaneous end uses deserve attention as well, despite not contributing as much to overall consumption. Unique barriers stand in the way of electrification of cooking and several other small but common energy end uses.

Cooking

A majority of cooking energy use is already electrified in Pennsylvania, but many households and businesses still rely on natural gas and propane to fuel their stoves and grills. As shown in Figure 41 and Figure 42, 65 percent of stoves in the residential sector and 40 percent of commercial building cooking equipment are electric, with natural gas accounting for all but 6 percent of the balance in both sectors.

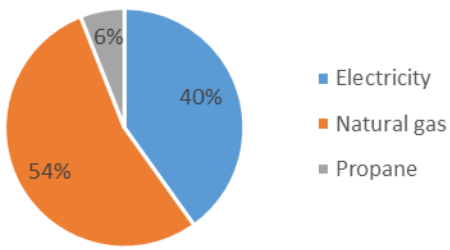
[126] National averages are used because water heating energy end-use data specific to Pennsylvania is not available to the authors' knowledge, and CBECS regional Mid-Atlantic state data provides only equipment data—not actual energy consumption by fuel type for water heating.

Figure 41. Residential stoves by energy source in Pennsylvania, 2009



Source: EIA. "Table HC3.8 Home Appliances in Homes in Northeast Region, Divisions, and States, 2009." Residential Energy Consumption Survey.

Figure 42. Commercial buildings cooking equipment by energy source in Mid-Atlantic states, 2012



Source: EIA. "Table B4. Census Region and Division, Number of Buildings, 2012." Commercial Buildings Energy Consumption Survey.

While commercially available substitutes for natural gas and propane-based cooking equipment exist, natural gas ranges and propane-consuming grills remain desirable cooking equipment for many consumers. Cooking equipment offers an example of how personal preferences and habits can present challenges to the complete elimination of all non-electric appliances.

Other

There are a number of miscellaneous end uses in the residential and commercial sectors that, while accounting for a small proportion of total energy consumption, have not been fully electrified. For example, backup power systems often utilize diesel generators. In the residential sector, these end uses also include gasoline-powered lawnmowers and landscaping equipment, propane and charcoal grills, and natural gas-based clothes dryers, which are used in 12 percent of Pennsylvania homes.[127]

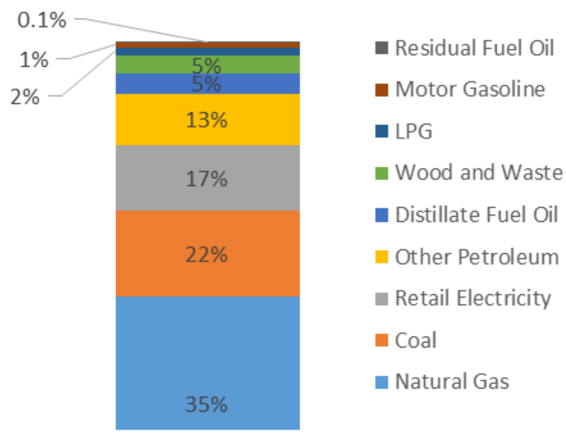
Natural gas chillers in the commercial sector are an alternative to electric motor-powered chillers for building owners. Natural gas chillers historically have been economically attractive when gas prices are low and the building owner is subject to an electric rate with a significant demand charge.

[127] EIA. 2009. "Table HC3.8 Home Appliances in Homes in Northeast Regions, Divisions, and States, 2009." Accessed May 4, 2016. www.eia.gov/consumption/residential/data/2009/#appliances.

5.4. Industrial Sector

Responsible for approximately 35 percent of energy use in 2013, the industrial sector is the largest energy user in Pennsylvania.[128] Along with the transportation sector, this sector arguably presents some challenges to complete electrification using water, wind, and solar. Some industrial end uses are difficult to electrify with technology readily available today. Figure 43 illustrates the diversity of fuel consumption in the Pennsylvania industrial sector, with only 17 percent from retail electric purchases in 2013.

Figure 43. Pennsylvania industrial sector energy consumption, 2013

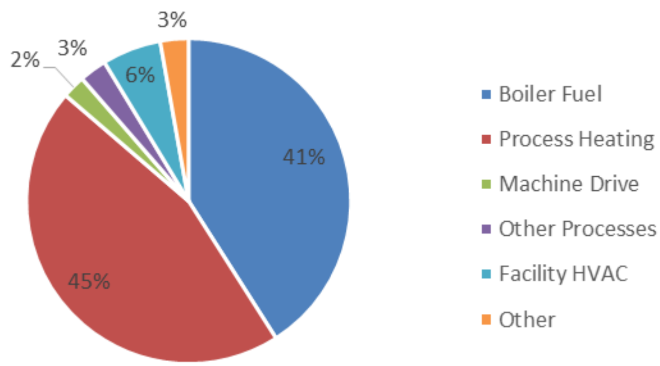


Source: EIA. "Table CT6: Industrial Sector Energy Consumption Estimates, 1960-2013."

Figure 44 illustrates that the vast majority of natural gas consumption in the Northeast's industrial sector is used for process heating (45 percent) and boiler fuel (41 percent) (i.e., CHP, cogeneration, and conventional boiler use).

[128] EIA. 2013."Table F30: Total Energy Consumption, Price, and Expenditure Estimates." Accessed April 13, 2016. www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_fuel/html/fuel_te.html&sid=US&sid=PA.

Figure 44. Industrial sector natural gas consumption by end use in the Northeast Census Region, 2010



Source: EIA. "Table 5.8: End Uses of Fuel Consumption, 2010." Manufacturing Energy Consumption Survey.

Process heating

Process heating is used in many industrial manufacturing operations, including non-metal and metal melting, calcining, metal heat treating and reheating, coking, drying, curing and forming, and fluid heating.[129] Non-metal melting, metal melting and smelting, and coking used in iron-making, among other applications, can require extremely high temperatures (2000-3000 degrees Fahrenheit). Furnaces, heat exchangers, evaporators, kilns, and dryers are examples of industrial equipment using process heating systems. High temperature energy uses such as process heating do not yet have commercially available solutions for a transition to electric power.

While natural gas is the primary fossil fuel used for industrial process heating, coal is used for process heating in a variety of industries. These range from food processing to chemical manufacturing to paper and cement production. A coal byproduct, coke, is used almost exclusively by the primary metals manufacturing industry to produce iron and steel.[130]

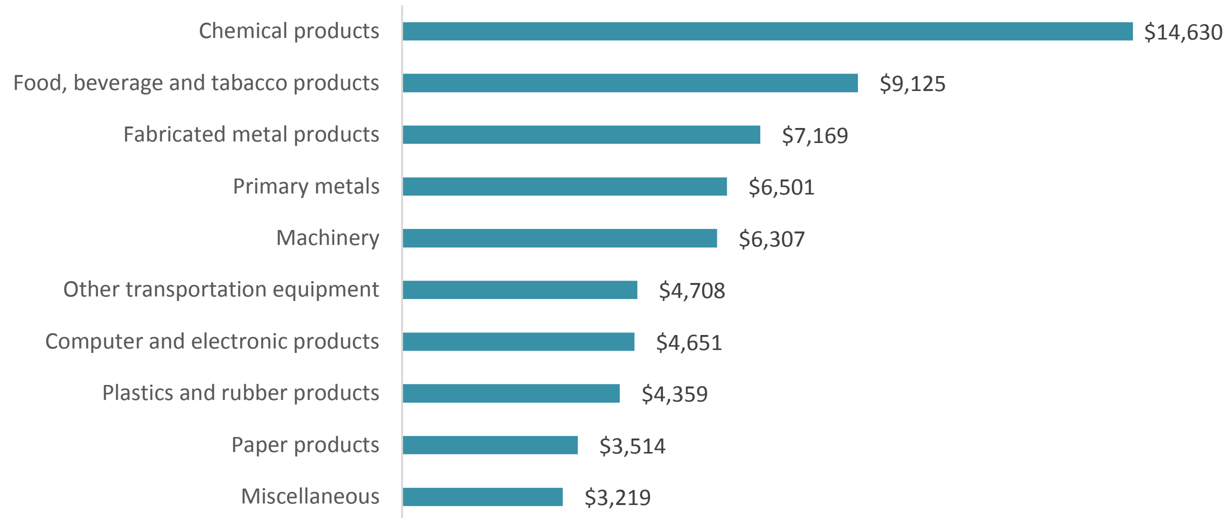
Use as a feedstock

Pennsylvania is a prolific manufacturing state, with the largest industries including chemical products; food, beverage, and tobacco products; and fabricated metal products (Figure 45).

[129] US DOE. "Industrial Process Heating – Technology Assessment [Draft]." Accessed April 28, 2016. www.energy.gov/sites/prod/files/2015/02/f19/QTR%20Ch8%20-%20Process%20Heating%20TA%20Feb-13-2015.pdf, Table 1.

[130] EIA. 2010 Manufacturing Energy Consumption Survey. Table 1.2. Consumption of Energy for All Purposes. By Industry and Region.

Figure 45. Top 10 Pennsylvania manufacturing sectors, in millions of dollars, 2013



Source: Center for Manufacturing Research. Pennsylvania Manufacturing Facts. Revised March 2016.

In addition to having high energy demands, the manufacturing industry consumes fossil fuels, including natural gas, liquefied petroleum gases (LPG), natural gas liquids (NGL), and coal (or coke), as non-fuel feedstocks in the production of chemicals, plastics, fertilizer, and primary metals. Overall, based on energy content, non-fuel uses make up roughly one-third of natural gas, LPG, NGL, and coal/coke use in the manufacturing sector. NGL and LPG are used almost exclusively for non-fuel purposes, while percentages of other fossil fuels for this use range from roughly 10 percent for natural gas to 35 percent for coal. The chemical manufacturing industry is the most prominent user of fossil fuels as a feedstock, primarily (75 percent) liquefied petroleum gases and natural gas liquids. The primary metals manufacturing industry uses both coal and coke as feedstocks, almost exclusively in the production of iron and steel. In primary metals manufacturing, roughly 94 percent of coal energy content is classified as feedstock use.[131] With a large presence of industries such as chemical and plastics manufacturing and the production of primary metals, the Pennsylvania industrial sector overall consumes a substantial quantity of fossil fuels for use as a feedstock.

While these non-fuel uses of fossil fuels are significant, our analysis does not directly address electrification or substitution of fossil fuels as feed stocks for non-fuel uses, as its focus is confined to energy use in Pennsylvania.

[131] EIA. 2010 Manufacturing Energy Consumption Survey. Table 1.2. Consumption of Energy for All Purposes. By Industry and Region and Table 2.2. Energy Used as a Nonfuel (Feedstock). By Industry and Region. Accessed May 2, 2016.

5.5. Pennsylvania's Electrification Efforts to Date

Pennsylvania has not undertaken substantial efforts to date regarding direct promotion of electrification as a clean energy opportunity. Rather, some efforts have actually encouraged fuel switching to natural gas in lieu of either electrification or petroleum-based fuels.

For example, the PUC initiated the Fuel Switching Working Group in 2009 with the responsibility to examine, identify, research, and address issues related to fuel switching. The aim was to see if it should be permitted or encouraged as a demand-side management resource or option for meeting energy reduction requirements under the state's energy efficiency and conservation plan.[132] The Commission adopted the working group's recommendation to make cost-effective fuel-switching measures eligible for incentives under the state's energy efficiency and conservation program. Utility energy efficiency programs are required under Pennsylvania's energy efficiency resource standard, the Energy Efficiency and Conservation Program. This program sets utility-specific reductions in electric retail sales to be achieved in a given timeframe. The Commission's decision allowed utilities to offer incentives to customers for installing certain equipment and appliances that use natural gas, rather than electricity, as its energy source, moving Pennsylvania farther away from full electrification.

More recently, the State Energy Plan identified fuel switching from petroleum-based fuels to natural gas in the transportation sector as an opportunity to be further pursued.[133]

Despite some policies and incentives encouraging fuel switching, some Pennsylvania energy efficiency programs have provided incentives that increase the financial attractiveness of energy-efficient electric water heating and space heating. In addition, renewable energy incentives have indirectly promoted carbon-free energy alternatives to fossil fuels. For example, several Pennsylvania electric utilities offer rebates for energy-efficient electric space and water heating equipment. FirstEnergy utilities offer a $400 rebate for air-source heat pumps, a $600 rebate for geothermal heat pumps, and a $500 rebate for solar water heating.[134] PPL offers a $300 rebate for heat pump water heaters, a $100-$200 rebate for air source heat pumps.[135]

In the national context, non-fossil fuel-based and energy-efficient space heating and water heating technologies are encouraged and directly incentivized. For example, energy-efficient electric heat pump water heaters are eligible for a federal residential energy efficiency tax credit of $300 if installed by the

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[132] PA PUC. 2010. "The Act 129 Fuel Switching Working Group Staff Report." Docket No. M-00051865, April 30. Accessed May 5, 2016. www.puc.state.pa.us/filing_resources/issues_laws_regulations/act_129_information/fuel_switching_working_group.aspx.

[133] Corbett, T, Pennsylvania State Energy Plan.

[134] NC Clean Energy Technology Center. "First Energy (MetEdison, Penelec, Penn Power, West Penn Power) – Residential Energy Efficiency Programs. Accessed April 29, 2016. www.programs.dsireusa.org/system/program/detail/4133.

[135] NC Clean Energy Technology Center. "PPL Electric Utilities – Residential Energy Efficiency Rebate Program." Accessed April 29, 2016. www.programs.dsireusa.org/system/program/detail/3854.

end of 2016.[136] Solar hot water heating is eligible for a 30 percent tax credit if installed by the end of 2019, 26 percent in 2020, and 22 percent in 2021. Geothermal heat pumps are eligible for a 30 percent (residential) or 10 percent (commercial) tax credit if installed by the end of 2016.

These incentives represent a first step in the promotion of energy-efficient space heating and water heating electrification; however, a substantially more comprehensive and ambitious set of policies will be needed to rapidly propel end-use electrification going forward. Vermont's strategic electrification program, which sets fossil fuel reduction targets, offers an example of an existing state policy designed to promote energy-efficient electrification.[137]

5.6. Electrification Options

As shown in Table 9, there are a broad range of technologies available for electrifying most end uses in the residential, commercial, and industrial sectors.

Table 9. Electrification options

Sector	End Use	Electrification/Renewable Opportunities
Residential and Commercial	Heating	Electric heat pumps (ground-, air-, or water-source) Electric resistance heating Building insulation and high-efficiency windows
	Water heating	Heat pump water heating Solar water heating
	Other Clothes Drying Cooking Yard and Landscaping Backup generation	Electric clothes dryer Electric induction or resistance-heating Electric or push lawnmower; native landscaping Solar + storage
Industrial	High-temperature industrial process heating	Electric arc furnaces Induction furnaces Dielectric heaters Resistance heaters Combusted electrolytic hydrogen

Source: Jacobson, M. et al. "100 percent Clean and Renewable Wind, Water, and Sunlight for the 50 United States." Energy & Environ. Sci. 8 (2015): 2093-2117. Supplemented by EQ Research and Synapse Energy Economics.

[136] NC Clean Energy Technology Center. "Residential Energy Efficiency Tax Credit." Database of State Incentives for Renewables and Efficiency. Accessed April 29, 2016. http://programs.dsireusa.org/system/program/detail/1274.

[137] Northeast Energy Efficiency Partnerships. 2015. "Vermont Embarks Upon Landmark Strategic Electrification Program." *www.neep.org,* December 18. www.neep.org/blog/vermont-embarks-upon-landmark-strategic-electrification-program.

For decades, natural gas was viewed as an environmentally preferable option for space heating and water heating if an end user had access to it.[138] Today, that conventional wisdom has reversed. Put simply, all or nearly all fossil fuel combustion will need to be phased out to meet carbon reduction targets necessary for ensuring a high likelihood of avoiding catastrophic climate change. With technological advances improving the efficiency of space heating and water heating coupled with major reductions in the cost of renewable energy, electrification offers the best way forward today to achieving 100 percent renewable energy in Pennsylvania by 2050.

Unlike previous generations of heat pumps that were criticized for poor performance in colder climates, newer cold-climate heat pumps have proven highly efficient, adept at performing even in below-zero temperatures, and substantially cheaper than some alternatives like fuel-oil-based heating equipment.[139] For example, a ductless (mini-split) heat pump system can prevent heat loss associated with vents and ducts; and when paired with increased building insulation, mini-split heat pumps can meet the heating and cooling needs of households.

Air source heat pump space and water heating systems deployed today are 200 to 300 percent efficient, and geothermal heat pump systems can reach 400 percent efficiency. A 100 percent efficiency level means that all potential heat content is transformed into useful heat. When heating equipment exceeds 100 percent efficiency level, one unit of power produces several times that amount from the air and ground, respectively.[140]

Solar hot water heating has been available for decades, and although low natural gas prices have undercut more widespread adoption in recent years, this technology can play a meaningful role in meeting building water heating needs in Pennsylvania.

Miscellaneous end uses in the commercial and residential sectors, such as clothes drying and cooking, also have readily available electric alternatives. These and other technologies (see Table 9) that are already commercially available today can be implemented to achieve 100 percent electrification of the residential and commercial sectors by 2050.

Industrial energy uses can be more difficult to completely electrify, but Table 9 presents a number of options for feasibly electrifying the sector with some combustion of renewably sourced electrolytic hydrogen. With respect to primary metals manufacturing, specifically steel production, it is possible that the use of coal and coke could be eliminated through a combination of recycling and reuse of scrap

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138 Dennis, K. 2015. "Environmentally Beneficial Electrification: Electricity as the End-Use Option." *The Electricity Journal*, Vol. 28, Iss. 9.

139 Newsham, J. 2015. "As Electricity Costs Rise, Market for Heat Pumps Takes Off." *Boston Globe*, October 6. Accessed April 29, 2016. www.bostonglobe.com/business/2014/10/05/new-heat-pump-technology-can-warm-homes-even-cold-new-england-winters/JgABf7wNFqRcYI6YVN6nsI/story.html.

140 Dennis, K., Environmentally Beneficial Electrification.

metal, which does not require the use of coal, and technological advances that allow elemental iron to be separated from iron ore using electrolysis.

5.7. Targets for Heating and Water Heating Electrification

Pennsylvania already has a moderate proportion of homes and commercial buildings using electric space heating and water heating, demonstrating that these technologies are commercially available and can be substituted for fossil fuel-based systems.

To determine targets for this analysis, we use the U.S. Census Bureau's American Community Survey[141] for data on residential space heating, EIA's Residential Energy Consumption Survey[142] for data on residential water heating, and U.S. DOE's Building Energy Data Book[143] for data on commercial space heating and water heating.

Space heating

First, we estimate the current combined residential and commercial electrification of space heating in Pennsylvania. Approximately 22 percent[144] of residential and 16 percent[145] of commercial space heating equipment is currently electrified.

For the residential sector, the Residential Energy Consumption Survey provides a breakdown of equipment ages. Using this, we estimated an average equipment lifetime of residential heating equipment of 15 years based on this data, which shows that only roughly 40 percent of the existing fleet is 15 or more years old. From this starting point we applied a gradually increasing trend towards electrification in five-year increments with an assumption that all existing electrified heating systems would remain electric. Thus for each replacement cycle, a steadily increasing percentage of older fossil fuel heating systems are replaced with electric systems, as follows: 10 percent by 2020, 50 percent by 2030, 100 percent by 2040 and each year thereafter.

Because of the assumed 15-year lifetime, in order to achieve a complete transition by 2050, all replacements from 2035 onward require a switch to electric heating.

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[141] U.S. Census Bureau. 2014. *American Community Survey*. Accessed April 29, 2016. www.factfinder.census.gov/.

[142] EIA. 2009. *Residential Energy Consumption Survey*. Accessed April 29, 2016. www.eia.gov/consumption/residential/.

[143] US DOE. 2010. *Building Energy Data Book*. Accessed April 29, 2016. www.buildingsdatabook.eren.doe.gov/.

[144] U.S. Census Bureau. 2014. "House Heating Fuel [Pennsylvania]." *American Community Survey*. Accessed April 29, 2016. www.factfinder.census.gov/.

[145] US DOE. 2010. "3.1.4 2010 Commercial Energy End-Use Splits, by Fuel Type (Quadrillion Btu)." *Building Energy Data Book*. Accessed April 29, 2016. *www.buildingsdatabook.eren.doe.gov/TableView.aspx?table=3.1.4*. Note that electrification is estimated by adding renewable energy and site electric space heating fuel types together and dividing by the total for all space heating.

For the commercial buildings sector, granular data on appliance make-up and lifetimes was not available. The starting point for the commercial sector is based on national statistics on energy use for space heating in commercial buildings. Electrification of replacements in the commercial sector was trended roughly in line with that of the residential sector. While equipment used for space heating in the commercial sector (e.g., boilers) may have a longer lifetime than typical residential space heating equipment, we believe this assumption is reasonable given the lack of available detailed data and the fact that the existing commercial equipment is likely to be older in the first place. Combined residential and commercial space heating electrification targets proceed relatively slowly at first, then accelerate beginning in 2030. The final set of assumptions for the electrification of space heating for the residential and commercial sectors are in Table 10.

Table 10. Combined residential and commercial space heating targets

2020	2030	2040	2050
25%	40%	75%	100%

Water heating

A similar estimation methodology is used for the electrification of water heating. Approximately 41 percent[146] of residential and 21 percent[147] of commercial water heating equipment is electrified.

For the residential sector, an average equipment lifetime of 10 years was used, reflecting that only roughly 35 percent of the existing appliance stock is 10 or more years old. Because the penetration of electric water heating in the commercial sector has a much lower starting point than the residential sector, it is necessary to accelerate the electrification rate to achieve 100 percent electrification by 2050. This acceleration was focused in the later years of the electrification schedule such that commercial sector electrification proceeds at a faster rate of increase than the residential sector in 2030 and beyond. To arrive at a consolidated target schedule of electrification, the two sectors were weighted for each 5-year period based on their relative contributions to overall building energy use, 33 percent for the commercial sector and 66 percent for the residential sector. The target schedule in Table 11 features an accelerating rate of adoption of electric water heating equipment.

146 EIA. "Table HC8.8 Water Heating in U.S. Homes in Northeast Region, Divisions, and States, 2009."

147 US DOE. "3.1.4 2010 Commercial Energy End-Use Splits, by Fuel Type (Quadrillion Btu)." Note that electrification is estimated by adding renewable energy and site electric space heating fuel types together and dividing by the total for all space heating.

Table 11. Combined residential and commercial water heating targets

2020	2030	2040	2050
35%	45%	80%	100%

5.8. Policy Pathways

In the short-term, the existing appliance stock and low natural gas prices present a challenge for increased adoption of electric space and water heating across all sectors. Policies targeting replacing existing equipment will need to be designed to account for the long useful life of space heating and water heating equipment that may not need replacement for several decades. Absent a substantial change in natural gas pricing trends, policies that directly increase the financial attractiveness of electric options will be critical to increase adoption rates. A number of regulatory policy changes are also needed to augment adoption and address non-cost barriers.

Other challenges to electrification of space and water heating include difficulty in changing end-user preferences and habits (e.g., some find gas cooking preferable to electric cooking alternatives), a lack of commercially available technological substitution (e.g., some industrial end uses will require non-electric clean energy alternatives), and up-front costs associated with new HVAC and water heating systems. Strong price incentives, regulations, financing, and the continued advancement of clean energy technologies, such as those using combustion of renewably sourced electrolytic hydrogen, together offer a promising pathway forward. While there is no policy "silver bullet," a well-designed policy portfolio can overcome potential obstacles to a rapid pace of electrification.

The policy portfolio implemented to get to 100 percent water, wind, and solar by 2050 will need to consider existing building and appliance stocks compared to new ones, as well as specific industrial sector end uses for which the technologies needed for electrification are not yet commercially available.

Financial incentives

Financial incentives can directly reduce the cost of electric heating and water heating technologies, which compete with natural gas-based technologies on price. Utility-implemented energy efficiency programs have a long history of using rebates to promote such energy-efficient equipment in homes and commercial buildings. Given limited budgets, financial incentives can be designed to decrease over time or as adoption rates increase to reflect higher initial costs that decline as the adoption rates increase. For example, the successful Pennsylvania Sunshine program offered rebates for solar PV that declined in steps as capacity blocks were reserved. This type of declining block structure is or has been used in many similar state incentive programs, such as the California Solar Initiative and New York's ongoing NY-SUN suite of incentive offerings. In comparison, energy efficiency rebate amounts have typically been set administratively, only evaluated on an annual basis or less frequently, and available on a first-come, first-served basis until the program budget has been exhausted.

Rebates

Rebates for efficient new electric heat pumps have successfully been employed by many electric utilities. More than $80 million in energy efficiency and conservation incentives like rebates were disbursed by utilities under Pennsylvania's Energy Efficiency and Conservation Program in the 2014-2015 program year.[148] "Free-ridership" can be a concern for incentive programs. Free-ridership refers to a circumstance where consumers who would have otherwise adopted the efficiency measure claim the rebate, resulting in no additional efficiency increase beyond what would otherwise occurred in the absence of the rebate. For example, appliance and HVAC rebates exhibited the highest free-ridership under the state's residential programs according to the Statewide Evaluation Team, which notes that adjustments to program design can reduce free-ridership.[149] To target new construction, a program could provide specified rebates to builders for all-electric, high-efficiency homes and buildings.

Tax credits

An electric heat pump water heater meeting specific energy efficiency criteria is already eligible for a federal residential energy efficiency tax credit of $300 if installed by the end of 2016.[150] A similar state-level tax credit could incent electrification technologies for years after 2016.

Grants

Grants for electric heating and water heating technologies could be a useful incentive in limited cases, such as low-income housing or for new high-efficiency demonstration technologies. Grants could be an ideal mechanism for catalyzing the electrification of certain industrial processes that do not currently have low-cost alternatives to direct on-site fossil fuel combustion. They may not be appropriate for all sectors, as direct expenditures associated with providing cash payments can add up to large costs and other policy "nudges" can encourage electrification at a smaller cost to governments. Generally speaking, competitive-type grant programs are best suited to addressing novel or potentially complex projects that are not amenable to a standardized mass-market rebate structure.

Green building incentives

Incentives for high-efficiency, all-electric green buildings could take a number of forms, including direct financial incentives. In addition, reduced regulatory burden for green buildings, such as expedited permitting and reduced inspection costs, can incentivize electrification in new buildings. Making buildings ineligible for such an incentive if they consume any fossil fuels on-site can further strengthen such an incentive.

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[148] Statewide Evaluation Team. Act 129 Statewide Evaluator Annual Report: Program Year 6: June 1, 2014-May 31, 2015 (March 8, 2016), 3-7.

[149] Ibid, 4.

[150] NC Clean Energy Technology Center. "Residential Energy Efficiency Tax Credit." Database of State Incentives for Renewables and Efficiency. Accessed April 29, 2016. www.programs.dsireusa.org/system/program/detail/1274.

Financing

Because space heating and water heating systems are a large expense relative to household annual income, upfront costs can deter adoption of efficient, electrified technologies. Policies that open up new financing avenues can catalyze electrification trends more quickly than relying on historical equipment turnover rates.

PACE financing

A Pennsylvania statewide property-assessed clean energy (PACE) financing program that is standardized across local jurisdictions, similar to the efforts of the Connecticut Green Bank, could be an effective financing mechanism for electrification. This is especially true for the commercial and industrial sectors. PACE financing allows a homeowner or business to pay for the cost of an energy efficiency or renewable energy improvement through a special assessment on their property tax bill. The source of financing can be private capital or local government bonds. Because the PACE assessment is tied to the property, not the person or business using the building, it can offer advantages over traditional loans.

On-bill financing

Utility-led on-bill financing programs allow customers to pay the capital costs of electric equipment on their electric bill rather than through a lump-sum upfront payment. These programs could further open up access to capital for financing building retrofits that include space heating and water heating electrification technologies. This option may be an attractive offering for electric utilities looking to increase electricity demand by having customers switch from natural gas furnaces, and has been established by a number of utilities around the country for technologies like distributed renewable energy. Pairing on-bill financing with strict system energy efficiency requirements can also serve to reduce net energy load.

Revolving loan

A revolving loan fund providing low-interest loans could target high efficiency electrification among hard-to-reach populations. A benefit of a revolving loan fund relative to direct incentives like rebates and grants is that the funds are repaid over time and can therefore be used to make additional loans after repayment. This creates a potentially self-sustaining funding mechanism after the initial funding. To the extent that repayments are not sufficient to fund program administration costs, or the financing involves some form of interest rate subsidy, a revolving loan fund may still require a source of dedicated funding.

Taxes

State and local government can also indirectly promote electrification through policy changes that discourage or increase the cost of natural gas production, distribution, and consumption in Pennsylvania. For example, phased-in increases in taxes, fees, or royalties on natural gas production in the state could be used to fund programs and incentives encouraging electrification while potentially resulting in price increases on consumers, which would further incentivize switching to electric end uses.

Since low-priced natural gas currently disincentivizes a transition from natural-gas-based technologies to electrification, policies that increase the price of natural gas are likely to increase customer substitution over time to electrification options for space heating and water heating. The most direct method of doing this would be through a per-unit tax on natural gas consumption. A tax rate that started small and increased annually could provide stable price signals and allow customers to switch to electrification options over time. This approach would also avoid a price shock that could otherwise unfairly penalize customers unable to switch equipment in the short term. Revenue collected from such a tax could be specifically appropriated to provide rebates or other incentives for electric heat pump and water heating technologies, further accelerating adoption.

Encouraging heating and water heating alternatives

There are a number of ways state and local government can encourage electrification without any additional expenditures. Governments can lead by example and work to phase out all fossil fuel-based equipment at a quicker pace than private sector building stocks. They can also aggressively promote energy efficiency to reduce building space heating needs, and provide technical assistance and related resources to citizens.

Regulatory changes

Regulatory changes can remove electrification barriers and further incentivize electrification technologies by lowering the cost, requiring its use, or increasing the cost of competing technologies.

Building codes

Pennsylvania can adopt a building code requiring the use of electric heating and water heating options in new residential and commercial buildings.

Equipment sales tax exemption

Exempting sales tax on all electric heating and water heating equipment can reduce the upfront cost of technology adoption. Sales tax exemptions and sales tax "holidays" for energy efficient and renewable energy equipment have been used by many states to incentivize clean energy technologies.

Fuel sales tax exemption

Currently, sales of natural gas, electricity, steam and manufactured gas to residential customers is exempt from the state sales tax, though generally speaking commercial uses are not exempt.[151] This

[151] PA Code § 32.25.

exemption could be revised to exclude fossil fuels from the exemption for residential customers and extend an exemption for electricity sales to commercial customers. The former is likely to be more effective as an incentive to convert to electric-only use because commercial businesses can typically claim an income tax deduction for energy expenditures and the accompanying tax paid on those purchases.

Utility energy efficiency programs

Existing energy efficiency programs can be altered to prevent the eligibility of natural gas technologies. Equipment eligibility requirements could be based on lifetime greenhouse gas emissions, where the threshold for eligibility would become increasingly stringent over time until only renewable energy systems or electric systems were eligible.

Permitting and interconnection for natural gas distribution

Limiting the build-out of new natural gas pipelines and infrastructure and forbidding new buildings from connecting to natural gas distribution systems could help spur electric heating and water heating by reducing the availability and competitiveness of natural gas as an alternative.

Electric utility rates

Utility rates and tariffs specific to all-electric homes or businesses, or for electric water heating, can facilitate the adoption of electric end uses and are already in use by some electric utilities. Demand response programs for controllable electric water heating can provide a financial incentive to customers while also reducing utility costs associated with peak demand times.

Market forces

Natural gas utilities require substantial infrastructure in order to deliver natural gas to customers. In the short term, the costs of this infrastructure are fixed, insofar as these infrastructure investments tend to be long-lived and the cost does not change once an investment is made to expand the infrastructure. These costs are recovered by utilities over the long-term in the rates charged to customers. In an environment where the number of customers and sales of natural gas are increasing, the embedded infrastructure costs are shared over a progressively increasing number of customers and natural gas sales. This mitigates the need for rate increases needed to support new investments, maintain existing infrastructure, and recover the embedded costs of that infrastructure.

However, if sales decrease, the embedded costs must be recovered over fewer sales to fewer customers, requiring an increase in the prices charged to customers and decreasing the attractiveness of natural gas to new and existing customers. Thus the gradual electrification of energy use creates a feedback loop where lower sales cause price increases, leading to customer attrition, which in turn causes further prices increases and further customer attrition. Ultimately, at some point there is little or no need for incentives and/or other mechanisms to support electrification of stationary energy uses because the cost of natural gas service is far more expensive than meeting the same need with electricity. Given that relatively more fixed infrastructure is required to provide service to smaller customers than larger customers, the effects of this cycle should be seen first in the residential and small commercial sectors, and later for the largest industrial customers.

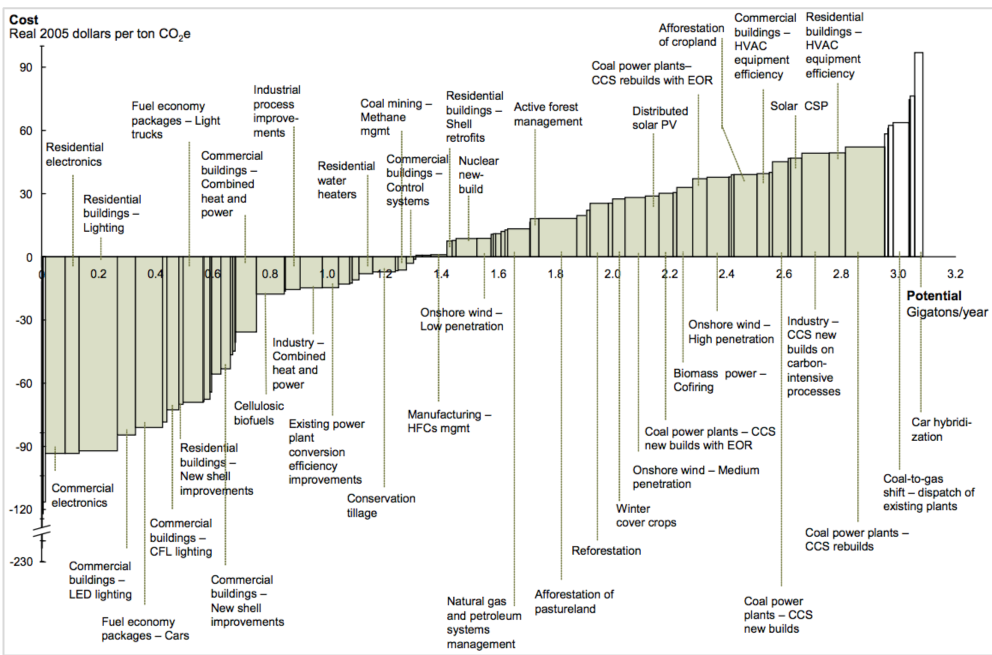
Importantly, the converse could be true of electricity prices. A major effort to electrify all energy end uses that generates a large increase in electricity sales allows infrastructure costs to be spread across more customers and sales, resulting in lower marginal costs.

Recently, Pennsylvania has been undertaking efforts to expand natural gas infrastructure within the state in order to deliver natural gas to additional in-state customers, as well as transport it out of state. In February 2016 the Governor's Pipeline Infrastructure Task Force (PITF) issued a report providing a series of recommendations for achieving a "responsible development" of pipeline infrastructure, and suggesting that state agencies assess those portions that fall within their purview for possible implementation. However, the underlying premise for the PITF effort, i.e. the need to make pipeline development easier, is highly questionable in an environment of increased electrification and declining use of natural gas. In light of this, we recommend that Pennsylvania reorient its efforts to evaluate the actual long-term needs for pipeline infrastructure and develop recommendations consistent with avoiding the development of new fixed infrastructure that will become increasingly obsolete as existing natural gas end uses are electrified. Among the areas to be revisited, along with the wisdom of expanding pipeline infrastructure in the state, would be recommendations for *strengthening* permitting rules and enforcement of those rules so as to protect Pennsylvania citizens from the adverse impacts of infrastructure development and operations.

6. INCREASED ENERGY EFFICIENCY

The cheapest and most environmentally friendly energy is the kind you never need to generate in the first place. Therefore, energy efficiency is not only an integral component of achieving ambitious clean energy targets, but is also an opportunity to reduce costs and save customers money. As shown in Figure 46, efficiency measures generally speaking are the most cost-effective at reducing greenhouse gas emissions, even before factoring in recent advancements and cost declines in technologies such as LED lights.

Figure 46. U.S. greenhouse gas emissions abatement cost curve, 2007



Source: Reproduced from McKinsey & Company. Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost? *December 2007.* Note: The Figure shows the cost-effectiveness of various greenhouse gas abatement measures, with the most cost-effective measures appearing on the left and the least cost-effective measures on the right. A negative cost indicates that the measure actually produces net benefits. The width of the bars indicates approximately how many gigatons of greenhouse gases per year the measure can abate.

Achieving a 100 percent renewable energy future in Pennsylvania will require rapidly scaling up the supply of renewable energy to meet the energy demands of the state, while simultaneously decreasing demand through end-use energy efficiency and conservation. This chapter considers the latter by describing Pennsylvania's efforts to date in becoming more energy efficient and identifying opportunities to increase efficiency through a suite of policy and regulatory changes.

Energy efficiency measures

Energy efficiency measures—broadly defined to include any technology, behavior, or practice that reduces total energy consumption while maintaining (or improving) the service provided by the energy—include improving overall building efficiency (e.g., insulation, air sealing, building envelop, etc.), retrofitting and proper maintenance of HVACs, appliances, and lighting that use fewer kWh, and changing habits to reduce consumption (e.g., not heating, cooling, or lighting unoccupied spaces). Building efficiency measures can reduce total electricity and on-site energy consumption by, for example, reducing electric load for air conditioning in the summer and natural gas consumption for a furnace in the winter.

This chapter principally addresses electricity end-use energy efficiency, including building energy efficiency in the residential, commercial, and industrial sectors; but several other types of measures that reduce energy consumption deserve a brief mention here. Implementing measures that (a) reduce electricity use during times of overall high demand and (b) even out electricity usage across time so there are not high "peaks" in usage, can allow the electric grid infrastructure to be sized more efficiently and avoid the need to use inefficient peaking plants or build new infrastructure. While this type of demand management can provide many benefits, this chapter focuses on the reduction of kWh (i.e., net electricity consumption), and not demand during specific time periods. Substantial inefficiencies inherent in combusting fossil fuels result in a substantial portion of the total energy being wasted in the form of released heat. This means that overall end-use electrification combined with generating electricity via wind, water, and solar energy will reduce the total primary energy demand of Pennsylvania, along with any end-use efficiency measures. Similarly, infrastructure improvements that increase efficiency and reduce energy losses in the generation, transmission, and distribution of electricity across the grid present other efficiency opportunities not explored further here. Finally, behind-the-meter on-site generation (e.g., rooftop solar PV) resembles an energy efficiency measure from the perspective of the electric utility insofar as it results in reduced customer electricity demand from the grid. These measures, while key to meeting clean energy targets, are not the present focus.

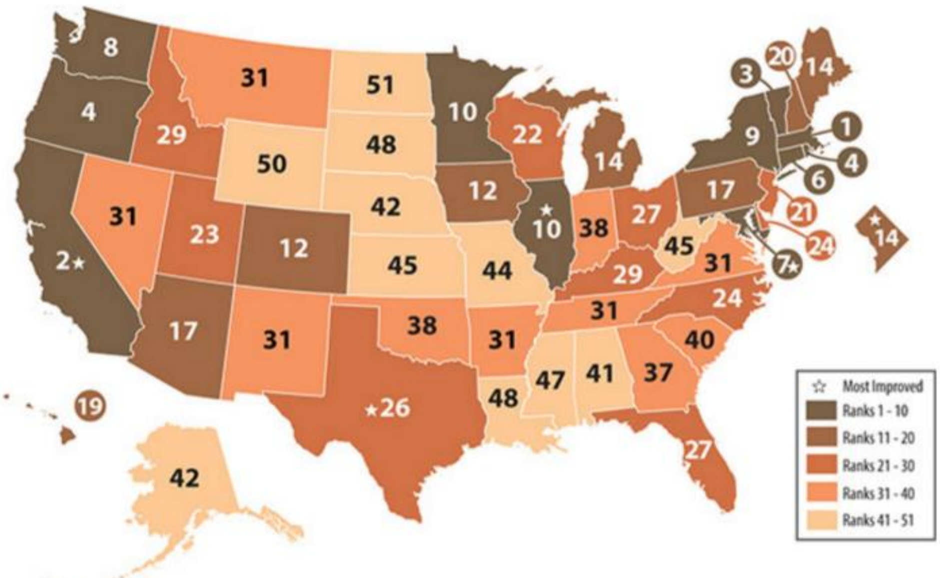
Energy efficiency targets for 2050

Our baseline modeling assumption for Pennsylvania is 1 percent annual incremental savings through energy efficiency. In comparison, Pennsylvania's energy efficiency and conservation program, discussed below in greater detail, sets individual sales reduction requirements for each large electric distribution company that are 1.6 percent to 2.9 percent below its baseline to be achieved over its current three-year compliance period. To achieve 100 percent renewable energy by 2050, we assume 3 percent annual incremental savings through energy efficiency. While an aggressive target, this is achievable through the suite of policies and programs discussed in the following sections.

6.1. Pennsylvania Energy Efficiency Policies

Pennsylvania has already enacted a multitude of policies and incentives to promote energy efficiency and induce the adoption of specific measures to cut energy consumption. As a result, Pennsylvania scored in the top half of states on energy efficiency, ranking 17th on the American Council for an Energy-Efficient Economy's (ACEEE) 2015 State Energy Efficiency Scorecard.[152] Only Maryland (7th), Illinois (10th), and Michigan (14th) scored higher among the 13 states participating in the PJM Interconnection (Figure 47).

Figure 47. ACEEE state energy efficiency scorecard, 2015



Source: Reproduced form ACEEE. "2015 State Energy Efficiency Scorecard."

Energy Efficiency and Conservation Program

The Energy Efficiency and Conservation (EE&C) Program, enacted as part of Act 129[153] in 2008, sets electric sales and demand reduction targets that apply to seven electric distribution companies (EDCs) in Pennsylvania that have at least 100,000 customers. During the program's first phase, applicable EDCs were required to reduce electricity by 1 percent for the compliance year ending on May 31, 2011 ("CY 2011") and 3 percent for CY 2013 relative to projected electricity consumption in CY 2010. Applicable EDCs were also required to reduce peak demand by 4.5 percent by the end of CY 2013 relative to CY 2008.

The Pennsylvania PUC is required to assess the cost-effectiveness of the EE&C program every five years and set additional incremental reductions in electricity sales if benefits exceed costs. Pursuant to this

[152] ACEEE, State Energy Efficiency Scorecard.

[153] Pennsylvania Public Utility Code at Sections 2806.1 and 2806.2, 66 Pa. C.S. §§ 2806.1 and 2806.2.

requirement, the PUC created Phase II (CY 2014 – CY 2016)[154] and Phase III (CY 2017 – CY 2021)[155] to extend the EE&C program, increasing EDC targets for reduced electricity sales as shown in Table 12.

Table 12. Pennsylvania utility energy efficiency resource standard, CY 2014-2021

Utility	Phase II (CY 2014 - CY 2016)		Phase III (CY 2017 - CY 2021)	
	MWh Reduction	% Reduction	MWh Reduction	% Reduction
PECO (Exelon)	1,125,851	2.90%	1,962,659	5.00%
PPL	821,072	2.10%	1,443,035	3.80%
Met-Ed (FirstEnergy)	337,753	2.30%	599,352	4.00%
West Penn (FirstEnergy)	337,533	1.60%	540,986	2.60%
Penelec (FirstEnergy)	318,813	2.20%	566,168	3.90%
Duquesne Light	276,722	2.00%	440,916	3.10%
Penn Power (FirstEnergy)	95,502	2.00%	157,371	3.30%
Total (MWh)/Average (%)	**3,313,246**	**2.16%**	**5,710,487**	**3.67%**

Applicable EDCs have met their efficiency and conservation requirements through developing EE&C plans that consist of multiple programs. Programs are typically sector-specific and provide incentives to customers for energy efficient equipment and buildings. EDCs outsource implementation of the programs via a Request for Proposals for a Conservation Service Provider, who conducts the marketing, outreach, administrative work, and rebate fulfillment.

Residential programs

Residential programs have provided customers with the knowledge, tools, and financial incentives to save energy. For example, Met-Ed residential programs include home energy kits, energy usage reports, and home energy audits that provide customer education and energy savings measures.[156] Customers can also take advantage of rebates for energy efficiency appliances to reduce the upfront cost of the energy efficiency measure. Residential customers with smart meters can also participate in a demand response program, whereby they receive notification messages to motivate reduced usage during demand response events, or times when electricity demand is highest and it is expensive to generate electricity.

Residential programs have also been used to specifically target low-income customers as well as new construction projects. For example, one of Duquesne's low-income efficiency Phase III programs is a low-income, whole house retrofit program that includes a home audit and the direct installation of up to

[154] Pennsylvania Public Utility Commission. *Implementation Order, Docket No. M-2012-2289411.* August 2, 2012.

[155] Pennsylvania Public Utility Commission. *Implementation Order, Docket No. M-2014-2424864.* June 11, 2015.

[156] Metropolitan Edison Company. 2015. Phase III Energy Efficiency & Conservation Plan. Accessed May 9, 2016. www.puc.pa.gov/pcdocs/1397216.pdf.

14 measures, including insulation, heating repair or replacement, heat pump water heaters, and refrigerator replacement, at no cost to customers.[157]

Nonresidential programs

Nonresidential programs include small commercial, large commercial, industrial, government, and nonprofit EE&C programs.

As for residential customers, EDCs offer nonresidential customers a number of incentives for energy efficiency measures. For example, as part of its Phase II plan, Penn Power offers subprograms for nonresidential customers that included prescriptive-based incentives for efficient HVAC equipment, ENERGY STAR® appliances and electronics, appliance recycling, lighting, food service equipment, agricultural equipment, building shell and systems improvement, multi-family building appliance replacement and audit, energy audits, and energy efficiency kits.[158]

Custom programs are a common offering as part of nonresidential sector EE&C programs. For example, PPL Electric provides financial incentives under its custom program for measures that include new or replacement energy efficient equipment, retro-commissioning, repairs, equipment optimization, building management or industrial process controls, new construction projects, combined heat and power ("CHP"), continuous energy improvement (e.g., behavioral and strategic energy initiatives), and operation and process improvements that result in cost-effective energy efficiency savings.[159]

EDCs owned by FirstEnergy offer a performance-based incentive for energy efficiency measures implemented by industrial customers in the amount of $0.05 per-kWh-saved. Performance-based incentives such as this are well suited for the industrial sector, which has very large, but diverse energy end uses that make it less well suited for technology-specific prescriptive rebates.[160] In contrast, FirstEnergy prescriptive rebates are typically a set pre-determined amount per unit (e.g., heat pump incentives are $150–$350 per unit), but can vary based on equipment size (e.g., incentives for efficient chillers are $12.50–$19 per ton).

Building codes

Building codes can promote whole building energy efficiency through uniform building construction standards that require, among other things, robust insulation, air sealing, and envelop testing. By

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[157] Duquesne Light Company. 2016. Revised Phase III Energy Efficiency and Conservation Plan. Accessed May 9, 2016. www.puc.pa.gov/pcdocs/1414169.pdf.

[158] Penn Power Company. 2015. *Phase III Energy Efficiency & Conservation Plan.* Accessed May 10, 2016. www.puc.pa.gov/pcdocs/1397225.pdf.

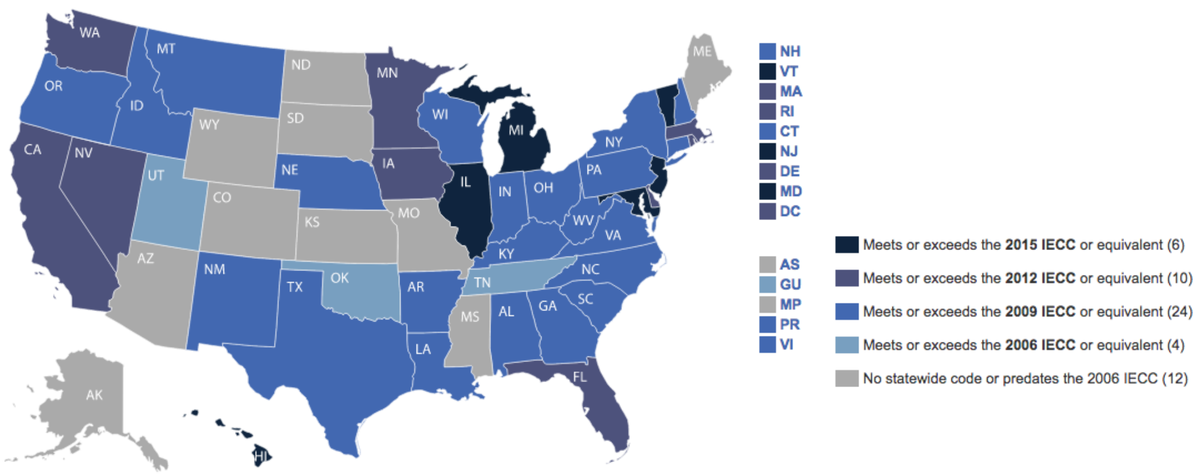
[159] PPL Electric Utilities Corporation. 2016. *Energy Efficiency and Conservation Plan: Act 129 Phase III*. Accessed May 9, 2016. www.puc.pa.gov/pcdocs/1438047.pdf.

[160] NC Clean Energy Technology Center. "FirstEnergy (Met-Ed, Penelec, Penn Power, and West Penn) - Commercial and Industrial Energy Efficiency Program." Database of State Incentives for Renewables and Efficiency. Last modified March 10, 2016. Accessed May 10, 2016. www.programs.dsireusa.org/system/program/detail/4132.

implementing building codes that get progressively more stringent over time, buildings will get increasingly energy efficient through the adoption of cost-effective design and technologies. In contrast, retrofitting an old building with energy efficiency upgrades is typically notably more expensive and difficult than incorporating the measures from the start.

The International Code Council (ICC) publishes the International Energy Conservation Code (IECC), a model code adopted by many state and local governments to address energy efficient building design. Pennsylvania's current building code, the 2009 Uniform Construction Code (UCC), is based on the 2009 International Energy Conservation Code (IECC) with reference to ASHRAE 90.1-2007. The 2009 UCC became effective on December 31, 2009.[161] The updated 2012 IECC and 2015 IECC and ASHRAEI 90.1-2010 and ASHRAEI 90.1-2013 have not been adopted by Pennsylvania, although some provisions of the 2015 IECC have been adopted in the residential code. As shown in Figure 48, Illinois, Michigan, Vermont, New Jersey, and Maryland have adopted the 2015 IECC for residential buildings, and California, Washington, Nevada, Minnesota, Iowa, Florida, Delaware, Massachusetts, and Rhode Island have adopted the 2012 IECC.

Figure 48. Adopted residential energy codes



Source: Reproduced from Building Codes Assistance Project. Accessed May 10, 2016.

The Department of Labor and Industry (DLI) is the authority charged with updating the state's energy code through the regulatory process. However, code updates proposed by DLI must gain two-thirds approval by the UCC Review and Advisory Council. Furthermore, DLI has no authority to enforce the code in local jurisdictions. Nevertheless, most municipalities have elected to enforce the 2009 UCC.

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161 Building Codes Assistance Project. "State Code Status: Pennsylvania." Accessed May 10, 2016. www.bcap-energy.org/code-status/state/pennsylvania/.

Green building codes

Green building codes can also be adopted by cities to supplement statewide building codes by including additional energy efficiency and renewable energy provisions, such as requiring that new buildings meet LEED certification standards or include an on-site renewable energy system. In 2009, Philadelphia enacted a green building code requiring all new construction or major renovation earn LEED Silver certification if a majority of the construction costs are funded by the city.[162] New construction must also meet or exceed ENERGY STAR cool roof standards.

Ongoing residential energy code field study

U.S. DOE is currently conducting a field study on the Pennsylvania Residential Energy Code that will last through 2017.[163] The agency is first conducting a baseline study to identify the average energy use in a typical Pennsylvania home. Then, DOE will provide education, training, and outreach focused on energy efficiency opportunities identified during the baseline study. Finally, a post-study will offer conclusions on the effectiveness of education, training, and outreach on energy consumption. Once completed, this field study will provide additional insight into Pennsylvania's residential building codes and opportunities to enhance energy efficiency in the residential sector.

State government building energy efficiency

An important role of state government in fostering the widespread adoption of energy efficiency measures is leading by example by adopting measures in state-government-owned or occupied buildings. A 2004 Executive Order[164] and a 2008 Management Directive[165] provide energy efficiency policies for Pennsylvania state government agencies. The 2004 Executive Order provided numerous behavioral and equipment energy efficiency measures to be implemented by state agencies, resulting in energy consumption reductions totaling 10 percent in 2006.[166] The 2008 Management Directive included measures to achieve an additional 10 percent reduction in energy use by 2010. Furthermore, Pennsylvania legislation enacted in 2013 requires new state buildings over 20,000 square feet achieve

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[162] NC Clean Energy Technology Center. "City of Philadelphia – Energy Standards for Public Buildings." Database of State Incentives for Renewables and Efficiency. Last modified November 25, 2014. Accessed May 10, 2016. www.programs.dsireusa.org/system/program/detail/4742.

[163] US DOE Office of Energy Efficiency and Renewable Energy. "Pennsylvania Residential Energy Code Field Study." Accessed May 10, 2016. www.energy.gov/eere/buildings/downloads/pennsylvania-residential-energy-code-field-study.

[164] Executive Order 2004-12. 2004. www.portal.state.pa.us/portal/server.pt/gateway/PTARGS_0_2_785_708_0_43/http%3B/pubcontent.state.pa.us/publishedcontent/publish/global/files/executive_orders/2000___2009/2004_12.pdf.

[165] Commonwealth of Pennsylvania. Management Directive 720.5 Amended. 2012. www.portal.state.pa.us/portal/server.pt/gateway/PTARGS_0_2_785_711_0_43/http%3B/pubcontent.state.pa.us/publishedcontent/publish/global/files/management_directives/commonwealth_programs/720_5.pdf.

[166] NC Clean Energy Technology Center. "Energy Management and Conservation in State Facilities." Database of State Incentives for Renewables and Efficiency. Last modified May 13, 2015. Accessed May 12, 2016. www.programs.dsireusa.org/system/program/detail/3133.

an ENERGY STAR rating of 75 or above. Finally, grants are available to cover a portion of the costs for designing new schools to meet LEED Silver certification or higher.[167]

Energy efficiency financing programs

Energy savings performance contracting

Local governments, schools, and other agencies can receive state funding to enter into an energy savings performance contract, which guarantees energy savings reductions through the implementation of specified efficiency measures without going through a time-consuming formal bid process.[168] The 2004 Executive Order described above encouraged Pennsylvania state government agencies to use energy savings performance contracting as well.

Alternative and clean energy program

Businesses, economic development organizations, and political subdivisions (including municipalities, counties, and school districts) in Pennsylvania are eligible to apply for a grant or loan under the state's Alternative and Clean Energy (ACE) Program.[169] The Department of Community and Economic Development and the Department of Environmental Protection, under the direction of the Commonwealth Financing Authority, administer the $165 million financial assistance program that can be used to implement a variety of energy efficiency and renewable energy projects.

Three financing mechanisms are available: loans (up to $5 million or 50 percent of the total project cost), grants (up to $2 million or 30 percent of the total project cost), and loan guarantees (up to $5 million for not more than a period of five years). Eligible clean energy projects related to energy efficiency include construction or renovation of a High Performance Building; site preparation of a business park with High Performance Buildings only; and installation of energy-efficient heating, lighting, and cooling equipment. Costs associated with preparing plans, specifications, studies, and surveys are eligible.

While the ACE Program can be used for implementing energy efficiency and renewable energy projects, projects related to fossil fuels (e.g., construction of compressed natural gas and liquefied natural gas fueling stations) are also eligible to apply.

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[167] NC Clean Energy Technology Center. "High Performance Green Schools Planning Grants." Database of State Incentives for Renewables and Efficiency. Last modified November 25, 2014. Accessed May 12, 2016. www.programs.dsireusa.org/system/program/detail/2314.

[168] ACEEE. "Pennsylvania." Accessed May 12, 2016. www.database.aceee.org/state/pennsylvania.

[169] NC Clean Energy Technology Center. "Alternative and Clean Energy Program." Database of State Incentives for Renewables and Efficiency. Last modified November 21, 2014. Accessed May 10, 2016. www.programs.dsireusa.org/system/program/detail/3650.

High performance building incentives program

The Department of Community and Economic Development and the Department of Environmental Protection, under the direction of the Commonwealth Finance Authority, jointly administer this $25 million grant and loan program.[170] Financing is provided for new construction and major renovations for buildings achieving LEED Gold certification. Project financing can be used for: project planning, design, and modeling; land acquisition, clearing, and preparation; registration and certification fees; commissioning and enhanced verification of building performance; and administrative costs related to the grant.

KeystoneHELP

The KeystoneHELP program provides fixed, low-interest loans to homeowners to finance energy efficiency upgrades.[171] Homeowners can apply for loans from $2,500 to $20,000 for 100 percent of project financing for terms of up to 10 years. Eligible projects include both whole-building measures like better insulation and air sealing in addition to efficient HVAC and appliance retrofits.

Small business advantage grant program

The Small Business Advantage Grant Program provides matching grants to businesses for up to $9,500 for projects that improve energy efficiency.[172] Administered by the Department of Environmental Protection, the program has a budget of $1 million and includes a broad range of eligible measures, including lighting, insulation, commercial equipment, motors, and ENERGY STAR appliances.

Sustainable energy fund

As part of electric utility restricting in Pennsylvania, four sustainable energy funds were created to promote renewable energy and clean-air technologies, including energy efficiency. To date, the funds have provided more than $20 million in loans and $1.8 million in grants across more than 100 projects.[173]

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[170] NC Clean Energy Technology Center. “High Performance Building Incentives Program.” Database of State Incentives for Renewables and Efficiency. Last modified May 4, 2015. Accessed May 12, 2016. www.programs.dsireusa.org/system/program/detail/3354.

[171] KeystoneHELP. “About.” Accessed May 12, 2016. https://keystonehelp.com/about/.

[172] NC Clean Energy Technology Center. “Small Business Advantage Grant Program.” Last modified January 8, 2016. Accessed May 12, 2016. www.programs.dsireusa.org/system/program/detail/1185.

[173] PA PUC. “Sustainable Energy Fund.” Accessed May 12, 2016. www.puc.state.pa.us/utility_industry/electricity/sustainable_energy_fund.aspx.

Weatherization assistance program

Residential customers can have an on-site energy audit conducted to determine which energy efficiency measures are most cost-effective for their homes.[174] Through the program, weatherization services include air sealing, installation of insulation, heating system replacement, minor repairs, and customer education. Customers earning less than 200 percent of the federal poverty line are eligible to apply, with the average per-household expenditure under the program being $6,500, although the services provided depend on the results of the energy audit.

6.2. Policy Pathways

Expanding existing programs

Energy efficiency resource standard

Energy efficiency resource standards (EERS) are one of the most effective policy tools to achieve energy savings.[175] In order to attain 100 percent renewable energy, Pennsylvania can expand on its existing EERS, the EE&C program, and the associated program incentives by ratcheting up its existing goal and setting targets for natural gas efficiency.

Individual state EERS's require annual energy savings ranging from 1 percent to 15 percent of reference consumption.[176] States with more aggressive efficiency targets include Hawaii, with an ultimate goal to reduce electricity consumption by 4,300 GWh by 2030, which is equal to 30 percent of forecasted electricity sales or 1.4 percent annual savings.[177] Massachusetts's EERS required incremental savings of 1.4 percent in 2010, increasing to 2.6 percent in 2015[178] and 2.93 percent in 2018.[179] In Rhode Island, the state's largest utility, National Grid, has a Least Cost Procurement mandate to engage in strategic long-term planning and investment in all efficiency measures that are cost-effective as part of its EERS. The annual savings requirement ramps up from 1.7 percent in 2012 to 2.6 percent by 2017.[180] Achieving

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[174] Pennsylvania Department of Community & Economic Development. "Weatherization Assistance Program (WX)." Accessed May 12, 2016. www.newpa.com/programs/weatherization-assistance-program-wx/#.VzTPQKODFBd.

[175] ACEEE. 2015. "State Energy Efficiency Resource Standards (EERS). Accessed May 10, 2016. www.aceee.org/sites/default/files/eers-04072015.pdf.

[176] NREL. 2014. "State Energy Efficiency Resource Standards: Design, Status, and Impacts." Accessed May 10, 2016. www.nrel.gov/docs/fy14osti/61023.pdf.

[177] ACEEE. "Hawaii." State and Local Policy Database. Accessed May 10, 2016. www.database.aceee.org/state/hawaii.

[178] ACEEE. "Massachusetts." State and Local Policy Database. Accessed May 10, 2016. www.database.aceee.org/state/massachusetts.

[179] Massachusetts Department of Public Utilities. 2015. *Massachusetts Joint Statewide Three-Year Electric and Gas Energy Efficiency Plan, 2016-2018.* Accessed May 19, 2016. www.ma-eeac.org/wordpress/wp-content/uploads/Exhibit-1-Gas-and-Electric-PAs-Plan-2016-2018-with-App-except-App-U.pdf

[180] ACEEE. "Rhode Island." State and Local Policy Database. Accessed May 19, 2016. www.database.aceee.org/state/rhode-island.

100 percent wind, water, and solar energy in Pennsylvania by 2050 will require bold state leadership in energy efficiency. However, based on the experience of state leaders to date, it is reasonable that Pennsylvania can increase the targets in its EE&C program to require annual electricity reductions of 3 percent and expand it to cover all utilities in the state.

Continued updates to building codes

Pennsylvania can use more stringent building codes to encourage energy efficiency. Improving building efficiency in the design stage is easier and less expensive than renovating buildings to be more efficient after construction, thus incorporating strong efficiency standards into state building codes can be one of the most cost-effective ways in which states can make efficiency improvements.[181]

As a starting point, Pennsylvania can update its building code, currently based on the 2009 IECC for commercial and residential buildings,[182] with the updated 2015 IECC code.[183] If adopted nationwide, the 2015 version of the IECC could result in $250 billion worth of emissions savings in 15 years.[184] Furthermore, adding a provision so that the building codes automatically update to the latest version of the IECC each time a new version is released can ensure the state is following the latest advancements in energy efficient buildings.

As Philadelphia has already done, Pennsylvania cities can go a step further and adopt green building codes to promote the acceleration of additional energy efficient, renewable energy, and electrification measures. Requiring LEED Platinum certification in all new or renovated commercial buildings and ENERGY STAR certification for new homes, which use 30 percent less energy than average homes, are examples of green building codes that could be adopted. Five California cities have enacted measures requiring new buildings to include on-site solar PV, which offers an innovative example of how building codes can be enhanced to promote specific clean energy technologies.

Adopting new programs

Appliance standards

Pennsylvania can set strong efficiency standards for appliances and equipment sold in the state. National standards have been set for many appliances, but some states adopt more stringent efficiency

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[181] International Energy Agency. 2008. *Energy Efficiency Requirements in Building Codes, Energy Efficiency Policies for New Buildings,* 7-8. Accessed May 10, 2016. www.iea.org/publications/freepublications/publication/Building_Codes.pdf.

[182] Building Codes Assistance Project. "State Code Status: Pennsylvania." www.bcap-energy.org/code-status/state/pennsylvania/.

[183] International Code Council. "Overview of the IECC." Accessed May 10, 2016. www.iccsafe.org/codes-tech-support/codes/2015-i-codes/iecc/.

[184] Natural Resources Defense Council. 2015. "Building Energy Codes in 2015: A Foundation of Cutting Climate Pollution." December 22. Accessed May 10, 2016. www.nrdc.org/experts/david-b-goldstein/building-energy-codes-2015-foundation-cutting-climate-pollution.

requirements, and state leaders can even drive the subsequent adoption of more stringent national standards.

Appliance efficiency standards are typically set in coordination with efficiency advocates and industry.[185] California has set the most ambitious efficiency standards for equipment or appliances; Arizona, Colorado, Connecticut, the District of Columbia, Maryland, New Hampshire, Oregon, Rhode Island, and Washington have also adopted a number of efficiency requirements that are stricter than those required nationally.[186] Pennsylvania regulators can convene stakeholder groups to assist in determining appropriately rigorous equipment efficiency standards using other state requirements and ENERGY STAR® standards as a guide.

Supportive financing programs

Financing programs can provide the upfront capital needed to help consumers make investments in efficiency upgrades. Different types of financing programs can be used depending on consumer type and preference.

As described in detail previously, Pennsylvania has already implemented a number of financing programs for energy efficiency. Continuing and expanding these programs will be key to the state's success and should be considered in addition to the expanded financing options presented here. In some cases, more narrowly tailoring existing programs to focus exclusively on clean energy measures would support renewable growth over fossil fuels. For instance, eliminating the option that allows projects related to fossil fuels to be eligible for the ACE program would remove an incentive for fossil fuels and provide additional funding for energy efficiency and renewable energy projects.

Funding for states to support energy efficiency financing programs can come from a number of sources in addition to general funds in a state budget. For example, revenues obtained from a carbon tax on polluters, from auctioned allowances as part of a state or regional cap-and-trade program, such as the Regional Greenhouse Gas Initiative (in which Pennsylvania is not currently a participant), or from a program developed to comply with the federal Clean Power Plan can be reinvested in clean energy financing programs designed to accelerate deployment and overcome existing market barriers.

PACE financing

Property assessed clean energy (PACE) is a financing mechanism designed to overcome challenges associated with traditional loan programs by avoiding down-payments and simplifying repayment for property owners.[187] State or local governments or inter-jurisdictional authorities provide the up-front cost of energy improvements, and participants repay the loan through a special assessment on their property tax bills. The debt is tied to the property rather than the property owner, so the debt may be

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[185] Appliance Standards Awareness Project. "The Basics." Accessed May 10, 2016. www.appliance-standards.org/standard-basics-DOE-state-legislature-product-requirements.

[186] Appliance Standards Awareness Project. "State Standards." Accessed May 10, 2016. www.appliance-standards.org/states.

[187] PACE Now. "What is Pace?" Accessed May 9, 2016. www.pacenation.us/about-pace/.

transferred to a new property owner. This removes the disincentive to invest in energy efficiency upgrades for property owners that may not know if they will own a property long enough to realize the cost savings of such investments.[188]

Green bank

A green bank is a financing institution that typically combines public and private funds to support clean energy projects through long-term financing. Green banks leverage public funds to attract private investment, multiplying the effectiveness of public funds.

Pennsylvania can expand on its existing Keystone HELP programs though creation of a green bank. In doing so, the state can increase the amount of available funds by adding private investments and scale up energy efficiency and renewable energy technology solutions more efficiently. State green banks can be created as separate, autonomous entities (as in Connecticut), or can be housed within an existing state agency, as New York and Hawaii have established their programs. [189]

On-bill financing

On-bill financing is a loan program option that allows customers to repay their energy efficiency loans through their utility bills. The payments are ideally set to be equal to the amount of energy efficiency savings, so that customers pay the same amount on their utility bills as they paid before the energy efficiency improvements were made. As with PACE financing, the loan can be tied to the property and transferred to a new owner, removing any disincentive for shorter-term property owners.

On-bill financing requires the collaboration of the utilities. Providing for on-bill financing will require utilities to modify their billing systems, in addition to policy changes that remove utility disincentives for energy efficiency inherent in the state's current ratemaking scheme (see below). Although utilities may not have the experience or expertise in house to implement on-bill financing, leveraging the existing billing relationship between utilities and customers can be more efficient and appealing to customers compared to setting up new loan repayment systems via a state agency, as is required with other financing programs.[190]

Building energy disclosure

Building energy disclosure or benchmarking laws make building energy use data available to property owners, potential buyers, program administrators, and policymakers. Such policies help building tenants and owners to understand a building's energy performance compared to other similar buildings. While

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[188] US DOE. "Property-Assessed Clean Energy Programs." Accessed May 10, 2016. www.energy.gov/eere/slsc/property-assessed-clean-energy-programs.

[189] Coalition for Green Capital. "What is a Green Bank?" Accessed May 10, 2016. www.coalitionforgreencapital.com/whats-a-green-bank.html.

[190] ACEEE. "On-Bill Financing for Energy Efficiency Improvements." Accessed May 10, 2016. www.aceee.org/sector/state-policy/toolkit/on-bill-financing.

these policies do not directly decrease energy consumption, they can help reduce energy consumption in the following ways:

- Requiring building owners to disclose energy usage may force them to pay more attention to their existing energy consumption; simply tracking energy usage in a more formal way could lead to changes in consumption. (As the adage goes, "You can't manage what you don't measure.")
- Energy consumption data can demonstrate to building owners and tenants where improvements can be made.
- Comparing energy consumption to similar buildings can have the "peer effect" of encouraging tenants and building owners to decrease energy consumption over a sustained period of time to match their peers.[191]
- Tenants or buyers may choose to lease or buy more energy efficient buildings, driving owners of less efficient buildings to make efficiency improvements to meet customer demand.[192]

Making detailed building energy usage data available to the public can also provide energy efficiency program administrators, including utilities and government agencies, with information that allows them to design more effective efficiency programs and may allow for targeted marketing of energy efficiency products.[193]

Pennsylvania can implement energy benchmarking as a complementary policy to other energy efficiency programs in order to drive energy efficiency investments.

Electricity industry policies

The previously described policies and programs are focused on providing electricity consumers with greater opportunities to make investments in energy efficiency improvements. By reducing costs, increasing information and awareness, providing financing, and requiring certain efficiency targets, these policies and programs are critical components for driving efficiency in the use of electricity. However, maximizing electric efficiency and meeting a 3 percent annual efficiency target will likely also require systemic changes in the way that electricity is provided to, and purchased by, consumers. This end involves aligning the motivations of both electric utilities and their customers, so that customers are

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[191] Ayres, I., S. Raseman, and A. Shih. 2013. "Evidence from Two Large Field Experiments that Peer Comparison Feedback Can Reduce Energy Usage." *Journal of Law, Economics, & Organization* 29: 5, 992-1022.

[192] Palmer, K. and M. Walls. 2014. *Can Benchmarking and Disclosure Laws Provide Incentives for Energy Efficiency Improvements in Commercial Buildings?* 10. Accessed May 9, 2016. www.mitei.mit.edu/system/files/2014-MITEI-Symposium-Palmer-Can-Benchmarking-and-Disclosure-Laws-Provide-Incentives-for-Energy-Efficiency-Improvements-in-Commercial-Buildings.pdf.

[193] Institute for Market Transformation. *Energy Benchmarking and Transparency.* Accessed May 9, 2016. www.imt.org/uploads/resources/files/IMTBenefitsofBenchmarking_Online_June2015.pdf.

rewarded for making investments and changing their behavior to be more efficient, and electric utilities are rewarded when their customers use energy more efficiently.

It is critical that policies address both consumer and utility motivations because one is much harder to achieve without the other. Investor-owned utilities, which are responsible for all but a small fraction of electricity sales in Pennsylvania, have a financial incentive to encourage energy consumption and resist energy efficiency because it reduces sales and therefore profits and the opportunity to provide a return to investors. Disregarding this so-called "throughput" incentive sets the stage for conflict, which can ultimately diminish the effectiveness of other mechanisms. That is, electric utilities can and should be considered valuable partners in maximizing energy efficiency; but securing their cooperation requires eliminating the disincentive for energy efficiency inherent in the existing way utilities earn revenue, and further, creating a system that rewards them for prioritizing energy efficiency as a resource.

In this subsection we first address consumer-focused ratemaking policies that support energy efficiency, then describe policies that can be used to align utility motivations and behavior with greater energy efficiency. It should also be noted that utility revenue and rate design is a complex exercise of balancing a variety of competing objectives that are often in conflict with one another. Our purpose here is not to assess how the following policy mechanisms align with all of those objectives. Instead it is to describe policies that are consistent with maximizing energy efficiency, or stated another way, establish maximizing energy efficiency as *the primary and most important objective* in utility ratemaking.

Changing consumer behavior

Inclining or inverted block rates

An inclining block rate electricity rate design, also referred to as an inverted block rate design, charges higher prices for higher levels of electricity use within a billing (i.e., monthly) period. For example, this type of rate structure may charge a residential customer $0.08 per kilowatt-hour (kWh) for all electricity purchases in a month up to the first 500 kWh consumed, $0.10 per kWh for the next 500 kWh (i.e., up to 1,000 kWh), and $0.15 per kWh for all monthly consumption in excess of 1,000 kWh during a month. By charging an electric customer progressively more as they use greater amounts of electricity, inverted block rates send a price signal to the customer that energy savings are valuable. The design tends to reward those customers that use less electricity than the average customer within their customer class (e.g., residential, small commercial). The steeper the incline, the larger the incentive customers have to conserve electricity. Pennsylvania has not widely adopted inclining block rates, although PECO previously had inclining block rates for residential customers in summer months.[194]

There are many potential questions that need to be answered in considering an inverted block rate structure. First among these is whether and how they should be applied to different types of customers. For instance, high usage by a residential customer may be looked upon as "discretionary" or "luxury"

[194] PA PUC. 2011. *American Recovery and Reinvestment Act Investigation I-2009-2099881: Working Group Final Report,* 64. January 24. Accessed May 19, 2016. www.puc.state.pa.us/general/RegulatoryInfo/pdf/ARRA_WG-Final_Report.pdf.

usage, whereas two commercial customers in the same customer class could have dramatically different levels of consumption simply because of the differing requirements of their businesses (e.g., a grocery store will have different energy demand compared to a gas station). Under these circumstances, inverted block rates may be considered punitive.

Another important question is how the rates themselves are set in terms of the number of blocks and the prices for those blocks. Steeply tiered prices with three or more blocks could be more effective at supporting energy efficiency, but it may not necessarily align with other important ratemaking principles (e.g., the highest tier may be priced much higher than the cost of that electricity, which would go against the principle of cost causation).

Ultimately, the design of customer rates can balance the goals of inducing customer energy conservation without undermining other key ratemaking goals. The establishment of energy efficiency as a state policy and ratemaking priority gives regulators discretion to make these types of judgments. Based on a review of Pennsylvania utility distribution and energy supply tariffs, inverted block rates are not presently used in the state, and represent a potential opportunity to create more effective price signals to customers to take action to reduce energy consumption.

<u>Reduced or eliminated fixed charges</u>

A typical electric utility customer’s rate contains a monthly fixed charge, energy charges (based on kWh consumed), and in the case of many nonresidential customers, a demand charge (based on a customer’s peak demand in *kW*). The energy and demand charges a customer accrues during a billing period are to varying degrees within their control. A customer can reduce these charges by making behavioral changes or investments in energy efficiency improvements. Fixed charges, however, are unavoidable and discourage energy efficiency in two ways. First, the customer pays the same fixed charge no matter how much electricity they consume during a month, so the fixed charge does not provide a price signal that supports conservation. Second, the fixed charge reduces the amount of revenue that must be raised from variable charges (i.e., energy and demand charges) in order to recover a utility’s costs to serve a customer, reducing the variable components of the electricity rate. Since the variable components are the savings a customer accrues from efficiency measures, lower variable charges reduce the incentive to conserve energy.

Pennsylvania’s utilities have gained approval from regulators to implement fixed charges as a component on electricity bills. Current residential customer fixed charges fall roughly in the middle of the range compared to utilities throughout the rest of the country at roughly $10 per month, with some variation across EDCs. However, in their latest rate cases filed in April 2016, the four Pennsylvania utilities owned by FirstEnergy requested large increases to residential fixed charges, which would increase to more than $17 per month in some cases. This comes against a backdrop of an ongoing debate on the role that fixed charges should play in electricity rates and how those rates should be set. Ultimately, there are a number of reasons that argue for a reduction or elimination of fixed charges beyond the detrimental effects that they have on consumer energy efficiency incentives.

One alternative to fixed charges or increases in fixed charges that has been adopted in some jurisdictions is a minimum bill.[195] Under a minimum bill, the customer pays a monthly minimum only when their bill would have otherwise fallen below the established minimum amount if based only on other charges. In contrast, a fixed charge is *in addition to* all other charges assessed on a customer. While minimum bill designs vary, the design that is best aligned with supporting energy efficiency is one that eliminates the fixed charge entirely and sets the minimum bill amount at a level sufficient to recover only a narrow set of costs. This set include those associated with customer metering, billing, and infrastructure devoted to serving that specific customer. In July 2015, California adopted this general approach for its investor-owned utilities, establishing a $10 per month residential minimum bill rather than instituting monthly fixed charges.[196]

While this example relates to the residential sector, minimum bills could also be applied to the non-residential sector. For larger customers, the design may be somewhat less critical for encouraging efficiency measures because the fixed charge is typically a smaller fraction of a larger customer's bill than it is for residential customers.

Other ratemaking measures

For larger nonresidential customers it may be more effective to pursue the elimination of minimum demand and demand ratchet provisions—common features of demand charges that limit customer control over their energy bills and dampen the conservation incentive—while also seeking more nuanced ratemaking solutions for very large customers that have unique usage patterns. A more customized approach to supporting energy efficiency through ratemaking for larger nonresidential customers recognizes that these customers tend to be far more aware of their energy costs and cost mitigation measures than residential customers because energy is a significant portion of their operating costs.

Utility policies

Energy efficiency as a priority resource

In order to establish a solid foundation for other policies that support energy efficiency, energy efficiency itself must be acknowledged as a resource and established as a priority. Many states have done this in some form, for instance, requiring demand-side resources to be evaluated in utility integrated resource plans (IRPs). Note that these requirements often come with qualifiers that the resources be "cost-effective," "economic," or "feasible." [197] How well the decisions made in these long-

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[195] Whited, M., T. Woolf, and J. Daniel. 2016. *Caught in a Fix: The Problem with Fixed Charges for Electricity.* Synapse Energy Economics. Note that non-residential customer classes are difficult to compare on an apples-to-apples basis because non-residential rate classes are not as homogenous as the residential class.

[196] California Public Utilities Commission. D.15-07-001. Rulemaking (R.) 12-06-013. July 13, 2015.

[197] ACEEE. "Energy Efficiency as a Resource." Accessed May 12, 2016. www.database.aceee.org/state/energy-efficiency-resource.

term planning exercises support energy efficiency is frequently dependent on how these terms are interpreted and tested. For instance, regulators must decide which tests to use to determine whether a given set of improvements are cost-effective, and what types of costs and benefits are included or excluded within the evaluation.

The states that rank highly on the ACEEE's state rankings have all established energy efficiency as a "priority" resource, which must be used to meet future supply needs as long as it is less expensive than other options. This practice is sometimes referred to as a "loading order" policy. In many cases, the prioritization of energy efficiency and references to cost-effectiveness are solidified with references to other state environmental and economic goals.[198] In Pennsylvania, Act 129 establishing the state's EE&C targets requires the adoption of utility energy conservation plans to implement "cost-effective energy efficiency," but stops short of establishing energy efficiency as a priority resource or requiring long-term planning efforts to maximize its use in meeting future needs.[199]

Adopting measures that define energy efficiency as a preferred resource and stating that maximizing the efficient use of electricity is a primary state policy goal would establish a justification for making utility EE&C program targets more aggressive. It would also establish a foundation for the adoption of other policies intended to support that outcome such as the ratemaking changes described in the following subsections.

Decoupling

Because energy efficiency measures reduce end-use energy consumption, and therefore utility revenues, traditional ratemaking policies schemes discourage utilities from promoting energy efficiency. Decoupling policies seek to overcome this barrier by disconnecting utility profits from its sales volume, in theory making a utility indifferent—rather than opposed—to efficiency and conservation by minimizing its throughput incentive.[200] It allows a utility to recover costs and the opportunity to earn a fair rate of return on its investments by setting the revenue target necessary for cost recovery and varying rates—typically through small, frequent adjustments—as overall consumption changes to ensure the revenue target is met. Adjustments can occur automatically each billing cycle or through a balancing account, where revenues from over-collection in one period can be used to offset under-collection in another period.

While decoupling alone provides an insufficient policy lever to propel rapid adoption of efficiency measures, it removes an existing barrier to efficiency and can complement other energy efficiency policies such as more ambitious EE&C programs. Importantly, decoupling only alters the utility's

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[198] Ibid. See for instance Vermont, California, Massachusetts and Connecticut.

[199] Pennsylvania Act 129. 2008. www.puc.pa.gov/electric/pdf/Act129/HB2200-Act129_Bill.pdf.

[200] Regulatory Assistance Project. 2011. *Revenues Regulation and Decoupling: A Guide to Theory and Application*. Accessed May 12, 2016. www.raponline.org/docs/RAP_RevenueRegulationandDecoupling_2011_04.pdf.

incentives, keeping in place the customer's incentive to implement cost-effective energy efficiency measures.

Performance-based ratemaking

In traditional cost-of-service regulation, regulators allow a utility the opportunity to earn a fair rate of return on its capital expenditures, thereby creating an incentive for the utility to have high sales and large capital expenditures. In contrast, performance-based ratemaking provides a financial incentive to the utility to reduce its costs. While there are several ways to implement performance-based ratemaking, they share several commonalities. Utilities are provided flexibility so that they can use their specific knowledge to reduce costs and are rewarded for improved operational efficiencies by having the opportunity to earn above-normal profit.[201]

Implementing performance-based ratemaking with specific performance targets for energy efficiency can create a powerful incentive for a utility to actively promote customer end-use energy efficiency. The explicit regulatory goal of increasing energy efficiency is implemented through performance target metrics where the utility is rewarded for exceeding performance targets and penalized for failing to meet the targets.

[201] King, R., D. Lewin, S. Isser, and J. Totten. 2016. *Efficiency and Ratemaking: Aligning the Interest of Utilities and Their Customers*. Accessed May 11, 2016. www.eepartnership.org/wp-content/uploads/2016/03/SPEER-Efficiency-and-Ratemaking-report-2.pdf.

7. PERMITTING AND SITING ENERGY INFRASTRUCTURE

The regulatory environment for energy infrastructure is crucial in determining a state's energy future; it sets the stage for the state's energy profile for decades to come. State policies that have paved the way for energy development can often have adverse effects on newer, typically cleaner types of energy resources. A state's laws and regulations determine the requirements and processes for extracting and transporting resources, generating energy, and delivering it to the end user. They also determine how various components and activities within the overall energy system are incentivized, frequently through the tax system but also through regulatory policies that facilitate or discourage different types of energy development. The design of these policies determines the state's energy path, both directly and indirectly.

Existing regulations governing the permitting and siting of energy infrastructure typically were originally developed with fossil fuels in mind. Frequently those regulations include exemptions and exclusions that implicitly support greater development of fossil fuel resources. At the same time, it is often the case that existing regulations do not fit the needs or considerations associated with renewable energy projects. Furthermore, financial incentives originally designed to spur energy development and allow for economic growth commonly still support fossil fuel resources, giving such resources an advantage over new technologies. Ultimately, these policies collectively undermine the competitiveness of renewable energy by driving up renewable energy deployment costs, and artificially or inequitably lowering the costs of traditional energy resources like fossil fuels.

This chapter examines regulatory incentives or disincentives for clean energy in three key categories. The first two categories, interconnection as well as permitting and siting, impact costs, transparency, and efficiency for renewable energy developers by addressing regulatory requirements to install renewable energy systems. The third is a critical disincentive to clean energy development in Pennsylvania: policies that incentivize and encourage the use of fossil fuel resources including coal and natural gas.

- **Interconnection procedures** determine the technical rules that must be followed in order to connect a system to the utility grid. Over the past several years, the United States has seen a resurgence of activity and interest in updating interconnection procedures at both the state and federal levels. This activity comes as utilities in several leading solar states, such as California, Hawaii, and Massachusetts have received high volumes of interconnection applications and, as a result, have had to update and innovate their procedures to incorporate increasingly higher penetrations of solar development onto the grid. While Pennsylvania has acceptable procedures for the current level of development in the state, it will likely need to update its procedures to efficiently accommodate a 100 percent renewable energy future.

- **Permitting and siting** represent a different type of challenge because they are implemented by local jurisdictions across the state and, as a result, can vary widely between local governments. Renewable energy developers who work across the state or even across a region of the state must understand and follow the variations in permitting and siting rules at the individual county, town, and city levels. When these processes are unclear or inefficient, additional labor costs are added to the total cost of the system, even apart from direct costs that may present themselves if a system requires a special use permit or a zoning variance. Transparency and basic consistency across jurisdictions can go a long way towards reducing these costs.

- Finally, to ensure a more even playing field, Pennsylvania can reexamine its policies that provide **incentives to fossil fuel resource extraction and consumption**. A recent report found that the average taxpayer in Pennsylvania paid $794 in subsidies to the fossil fuel industry in fiscal year 2012-2013, mostly in the form of tax breaks.[202] This chapter provides recommendations on improvements that can be made to the state's policies relating to fossil fuel extraction that serve as a major barrier to renewable energy deployment.

It is important to recognize that these regulatory policies are in place for a reason—to ensure the installation of safe and reliable renewable energy systems and to drive investment in energy-related businesses. However, outdated policies can be updated and improved to reflect current best practices as well as advances in technology and evolving energy markets. Moreover, the idea of improving basic consistency, efficiency, and ultimately regulatory certainty is in no way unique to the renewable energy industry and should not be construed as an effort to advantage renewable energy relative to other energy sources. Instead it should viewed as one element of leveling the playing field between renewable energy and fossil fuel energy resources, recognizing that over the years the fossil fuel industry has sought and received the benefits of similar policies.

7.1. Interconnection

Customers or businesses that install distributed generation—electric generating facilities installed at or near the point of consumption rather than at a centralized power plant—must connect to the utility's distribution system (or "the grid"). This process is known as interconnection. Interconnection rules set the technical requirements and procedures for connecting renewable energy systems to the electric grid. Comprehensive interconnection procedures ensure that utilities process interconnection applications from customers in a cost-effective, non-discriminatory, and efficient manner. Well-designed interconnection rules can facilitate the efficient growth of renewable energy, whereas poorly designed or out-of-date rules can put up road blocks for renewable energy and add costs and delays. These delays can have a negative impact on renewable energy companies and can push renewable energy industries out of the state. The easier the installation process is for businesses and customers, the faster renewable energy can grow.

Most state regulatory commissions have determined the basic rules and parameters that state-jurisdictional interconnection procedures must follow, but utilities are typically in charge of approving

[202] PennFuture. 2015. *Fossil Fuel Subsidy Report for Pennsylvania*, 5. Accessed May 31, 2016. www.pafossilfuelhandouts.org/wp-content/uploads/2015/04/FossilFuelSubsidyReport_PennFuture.pdf

individual system interconnections.[203] If a state has not adopted clear rules, or if rules have not been updated to reflect current best practices and emerging technologies, the interconnection process can be confusing, unclear, or redundant. These conditions can lead to slow and costly interconnection, impeding the transition to renewable energy.[204]

There are a number of resources available to help stakeholders understand and to help state decision-makers improve interconnection policies. The Interstate Renewable Energy Council (IREC) produces an annual scorecard called *Freeing the Grid*, which grades state interconnection policies.[205] IREC has also established model interconnection rules for states that can be used as a template for states as they update their procedures.[206] The model also contains helpful footnotes to explain important aspects of the process. In addition, for a better understanding of the rationale for recent improvements in interconnection policies, the National Renewable Energy Laboratory (NREL) has produced a detailed report titled *Updating Small Generator Interconnection Procedures for New Market Conditions.*[207]

Pennsylvania's current interconnection regulations

Under the *Freeing the Grid* grading regime, Pennsylvania currently earns a "B."[208] The state standards set out requirements only for EDC customers, and apply to systems of 2 MW or less. The requirements are broken out into four different interconnection levels, with different interconnection requirements and procedures based on system size, whether the equipment has been certified, the type of network or circuit the system will be connected to, and whether a system will export electricity.[209]

In the *Freeing the Grid* Report, IREC recommends that Pennsylvania expand its interconnection procedures to cover municipal utilities and electric cooperatives, and also to remove requirements for redundant external disconnect switches.[210] Though Pennsylvania's interconnection standards already meet several of IREC's suggestions, many states and utilities have been working to improve

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[203] State jurisdiction is reserved primarily for small systems that connect to the distribution system of an electric utility, rather than the transmission grid. Federal standards developed by the Federal Energy Regulatory Commission (FERC) govern larger projects, as well as some smaller projects that involve interstate sales of electricity.

[204] IREC. "Interconnection." *Freeingthegrid.org.* Accessed May 23, 2016. www.freeingthegrid.org/#education-center/interconnection/.

[205] IREC. "About FTG." *Freeingthegrid.org.* Accessed May 23, 2016. www.freeingthegrid.org/#about/introduction/.

[206] IREC. 2013. *Model Interconnection Procedures.* Accessed May 23, 2016. www.irecusa.org/publications/model-interconnection-procedures/.

[207] NREL. 2012."Updating Small Generator Interconnection Procedures for New Market Conditions." www.nrel.gov/docs/fy13osti/56790.pdf.

[208] IREC. "Pennsylvania - Interconnection." *Freeingthegrid.org.* Accessed May 23, 2016. www.freeingthegrid.org/#state-grades/pennsylvania.

[209] 52 Pa. Code § 75.21 et seq. Accessed May 23, 2016. www.pacode.com/secure/data/052/chapter75/subchapCtoc.html.

[210] IREC. "Pennsylvania - Interconnection." *Freeingthegrid.org.* Accessed May 23, 2016. www.freeingthegrid.org/#state-grades/pennsylvania

interconnection procedures beyond these recommendations, as technical advancements, experience, and collaboration across stakeholders have resulted in new solutions for streamlining the interconnection process.

Undertaking interconnection reforms

When undertaking the interconnection reform process, it is important for states to take a comprehensive view, rather than adopting a patchwork strategy. This will ensure that each aspect of the interconnection process operates efficiently and in concert with other distributed generation policies. As such, Pennsylvania can follow the actions of Ohio and other leading states by adopting the Federal Energy Regulatory Commission's (FERC) Small Generator Interconnection Procedures (SGIP) for state-jurisdictional interconnection, updated in 2013.[211] The updated SGIP reflects several innovative best practices that were being implemented in states with high penetrations of distributed energy resources, such as California and Hawaii. The FERC SGIP has three tiers for applicants that entail increasing levels of scrutiny: the simple Inverter Process for systems up to 10 kilowatts, the Fast-Track Process, and the Study Process. The updated version of the SGIP includes, among other things, three important additions that streamline the federal procedures:

1. A requirement that a pre-application report be made available to developers for a fee of $300. This report provides important information about the grid and its equipment in a particular area. Making this information readily available to the developer helps reduce the need for developers to submit speculative applications to determine the feasibility of projects.

2. An expansion of Fast-Track eligibility from 2 to up to 5 megawatts, depending on the proximity to substations and the line size to which it is connecting.

3. The addition of a supplemental review process for applications that fail the "15 percent rule," which is a holdover from a time when grid data was not as readily available as it is today. This rule is essentially an engineering estimate aimed to prevent any potentially harmful backfeeding from the line section to the circuit level of the grid. However, with the amount of smart grid technology that has been deployed, it is often easier to get a better estimate of actual, real-time grid data, rather than relying on a general rule-of-thumb estimate. Moreover, solar is the predominant distributed generation resource being interconnected to the grid and it typically produces during peak times of the day, when backfeeding is highly unlikely. As a result, the minimum load issue being screened for by the 15 percent rule is not typically very relevant. In essence, this additional supplemental review screen allows applications to be moved forward more cost-effectively when they do not pose a risk to grid safety and reliability.

[211] FERC. Updated 2016. Standard Interconnection Agreements and Procedures for Small Generators. Accessed June 7, 2016. www.ferc.gov/industries/electric/indus-act/gi/small-gen.asp.

While the FERC SGIP was adopted for systems interconnecting under federal jurisdiction, it was based on state procedures and was originally intended to be a model for states to follow.[212] If Pennsylvania were to adopt the FERC SGIP, it would also provide a more standardized, streamlined regulatory approach for distributed generation developers and help create more certainty in the market.

It is important to realize that interconnection reform not only makes the process more efficient for the customer or developer, it also improves efficiencies for utilities. By providing more transparency and information up front, utilities receive many fewer "speculative" applications that are submitted to gauge the costs and feasibility of interconnecting to a particular section of the grid. These speculative applications waste utility staff time, so utilities also have an incentive to make the process more efficient.

In addition to updated interconnection procedures, some utilities around the country are embarking on new initiatives to provide even more transparency and data to aid developers in the interconnection phase. PG&E in California, for example, is working with local jurisdictions and installers to achieve one of the fastest interconnection timelines in the country. Customers of California investor-owned utilities are not required to submit a pre-application for interconnection; instead, installers can check online to make sure a system can be installed on that section of the grid, and install the system without waiting for utility approval. After system installation, PG&E is working to allow local permitting officials to access its software system to load permit information immediately upon approval, allowing PG&E to approve the system to operate the same day.[213] Providing customers and installers with online application systems can allow for customers to check their application status and make any necessary updates or corrections to help speed up the process. As renewable energy and distributed generation become more common in Pennsylvania, regulators will need to be proactive in planning for and accommodating interconnection. Unnecessary delays that require otherwise fully operational facilities to sit idle both frustrates applicants and results in foregone clean energy production. When multiplied across thousands of small and large systems, even short delays can result in large amounts of lost, emission-free, electricity generation.

Beyond reform: planning to support distributed generation

Several utilities across the country have developed interconnection maps which provide developers with important information about the interconnection potential for solar, EVs, and battery storage in a given area of their service territory. This is sometimes referred to as "hosting capacity," referring to how much new distributed generation a given section of the grid can host within existing technical limitations. California's investor-owned utilities all provide interconnection maps; though, of the three, Southern

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[212] FERC. *FERC Order 2006,* p 513. www.ferc.gov/EventCalendar/Files/20050512110357-order2006.pdf.

[213] EQ Research. 2015. *Comparing Utility Interconnection Timelines for Small-Scale Solar PV*. Accessed May 23, 2016. www.eq-research.com/wp-content/uploads/2015/07/IC-PTO-Timeline-Report-7-2015.pdf.

California Edison has developed the most accessible online system. Illinois-based ComEd has also developed a grid-mapping tool for developers.[214]

In the mid- to long-term, fully realizing the contribution that renewable distributed generation can make to the state's energy mix will require a focused emphasis on evolving grid planning itself to support more renewables.[215] This type of revised planning structure is being pursued in states such as Hawaii and California, which already have relatively high penetrations of renewable distributed generation on the grid. Likewise, it is among the many issues being addressed in New York's larger *Reforming the Energy Vision (REV)* effort.[216]

While it may seem premature for some states with currently low penetrations of distributed generation to improve upon their interconnection procedures, it is important to remember that the solar market is forecasted for major growth across the country and that the interconnection reform process takes time. To prevent any major bottlenecks or slowdowns in the market, updated interconnection procedures should be in place *before* a state starts experiencing higher levels of distributed generation penetration. Similarly, the need for more advanced tools, such as interconnection penetration maps, becomes increasingly important as grid penetration grows and projects become more likely to encounter technical limitations that prevent an interconnection or require expensive upgrades.

7.2. Permitting and Siting

The siting and permitting process varies across renewable energy resources, project size, and location. Solar, wind, and hydroelectric facilities each raise unique issues that governments have a legitimate interest in regulating for public health, safety, economic, or environmental reasons. For example, since industrial wind turbines are often more than 300 feet high (including the blades), protections are needed to ensure they are not located so close to an airport that they would create a possible hazard for planes. Likewise, the siting and permitting process varies by a project size and location, with larger projects and those located on or near particular areas like airports, prime farmland, sensitive conservation areas, or bat or bird migratory routes potentially receiving different treatment.

Permitting and siting new large-scale renewable energy resources can involve a number of steps, including mapping and surveying the area; delineating wetlands; developing studies on the natural and cultural resources, geology, environmental impacts, noise impacts, drainage feasibility, and hydrology modeling; creating plans related to hazardous materials management, storm water pollution prevention, conservation, and decommissioning; obtaining local zoning permits, inspections, and

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[214] See SCE's mapping interface at www.arcgis.com/home/webmap/viewer.html?webmap=e62dfa24128b4329bfc8b27c4526f6b7; ComEd's map is available at www.comed.com/customer-service/rates-pricing/interconnection/Pages/distribution-under-10000kva.aspx.

[215] IREC. 2013. *Integrated Distribution Planning Concept Paper.* Accessed May 31, 2016. www.irecusa.org/integrated-distribution-planning-concept-paper/.

[216] New York Public Service Commission. Docket No. 14-M-0101.

engineering studies; and obtaining any necessary state or federal permits that apply. This process, though undeniably necessary, can be long, expensive, and difficult to navigate within overlapping jurisdictions and regulatory requirements. Smaller systems, principally *rooftop* solar PV, are typically only subject to a narrower subset of permitting requirements because they do not give rise to the same land use concerns as industrial renewable energy development. However, in some instances, the process can still prove challenging and constitute a meaningful portion of the total cost of installation.

The lack of planning, zoning, and permitting uniformity across jurisdictions, ambiguity in current regulations, and opaque processes are a major barrier for renewable energy developers during the development phase. For example, a renewable energy installer that is unable to navigate the permitting and siting requirements of local jurisdictions may choose not to do business in certain areas. Confusing requirements also make the process of installing renewable energy more time-consuming and costly. Moreover, long permitting processes that take years to complete can make it difficult for project developers to secure the funds needed to see a project through the entire installation process. More consistent procedures and requirements throughout a state allow installers to operate throughout the state more efficiently and cost-effectively. Consistency and efficiency is particularly important for smaller systems such as rooftop solar PV because the associated costs are spread over a much smaller total investment.

The state of Pennsylvania can take steps to improve this process by helping foster enhanced consistency across local government regulation. This could take the form of collaborating with local authorities to develop means to provide greater access to information, streamline processes, minimize additional costs and wait times, develop best practices and updated model ordinances, and promote consistency through technical assistance, education, and outreach. This is not to say that local permitting requirements should or must be entirely uniform. Local issues and differences should be respected, and should continue to be considered, addressed and protected through local regulation. However, significant efficiencies can be gained simply by making sure that requirements are clear and processes are efficient, while still allowing for variations that are consistent with local land-use planning goals. Furthermore, land-use planning should consider how renewable energy projects can be accommodated in light of local goals, and requirements or restrictions should be based on sound science and careful consideration of potential impacts (both positive and negative).

Current Pennsylvania regulations

Reasonable zoning and permitting regulations for renewable energy systems can promote increased deployment of renewable energy while reducing the likelihood that these systems are sited in a way that could lead to negative public health, safety, or aesthetic impacts. A lack of zoning and permitting regulation that clearly identifies the approval process for new renewable energy development can lead to a number of undesirable outcomes, including an increased risk of what the local government might consider to be inappropriate development, high internal review costs, and even a loss of development opportunities, as regulatory ambiguity or uncertainty can scare off potential investments.

Local government jurisdiction

Local governments retain significant autonomy to pass laws pertaining to its self-governance, including zoning codes. Specifically, Pennsylvania municipalities retain control over many siting and permitting regulations related to renewable energy systems by enacting zoning or subdivision and land development controls to regulate renewable energy systems. Zoning is the only option for a municipality to permit or prohibit renewable energy systems in specific areas.[217] Subdivision and land development controls allow a municipality to regulate aspects of a renewable energy project, including system type, location, height, setback, and vegetation screening requirements.[218] Projects that do not meet the requirements of a local ordinance can request a variance with the jurisdictional municipality's Zoning Hearing Board or Zoning Board of Adjustments. However, for small projects in particular, obtaining a zoning variance may be cost-prohibitive.

Since the development of a power plant in Pennsylvania is considered a land-use decision, local jurisdictions have primary discretion when it comes to siting projects. Zoning regulations vary by municipality, and some Pennsylvania municipalities do not have zoning regulations. Small renewable energy systems do not always fall within the purview of zoning regulations, with some jurisdictions treating these systems as an accessory use.

Permitting fees themselves (i.e., for building and electrical permits) can also be meaningful costs for small renewable energy projects, and widespread discrepancies exist in permitting fees and times across Pennsylvania. A 2012 study of solar PV permitting in 36 Pennsylvania municipalities found that most were using a value-based fee structure, where the fee varies by the system size or installed cost. This has the effect of penalizing larger systems even if that system does not necessarily require additional review or incremental local staff time relative to a smaller system. Only three municipalities used a flat fee structure, and only nine charged $250 or less (a flat fee under $250 is considered a best practice for residential systems). In the most expensive municipalities, an average residential solar PV system would be assessed a $1,200 permitting fee. 25 municipalities reported a two-week permitting turn-around time for residential systems, with nine issuing a permit within five days.[219]

State government jurisdiction

State regulations can also impact the siting and permitting of renewable energy projects throughout Pennsylvania. For example, the Pennsylvania DEP regulates the impact of renewable energy systems on water and wetlands, typically as it relates to road-building and construction. Utility-scale wind projects

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217 PA DEP. 2006. "Model Ordinance for Wind Energy Facilities in PA." Accessed May 31, 2016. www.dep.pa.gov/Business/Energy/Documents/wind_model_ordinance_draft_(12-8-06).doc?Mobile=1&Source=%2FBusiness%2FEnergy%2F_layouts%2Fmobile%2Fview.aspx%3FList%3Da6f15f72-5900-4bd0-a30e-28cb338ad402%26View%3D4c20eedc-f438-4516-b65f-47b4952fedd6%26CurrentPage%3D1.

218 Governor's Center for Local Government Services Pennsylvania Municipalities Planning Code: Act of 1968, P.L. 805, No. 247 as reenacted and amended. February 2005. http://mpc.landuselawinpa.com/MPCode.pdf

219 Vote Solar. 2012. "Survey of Solar Permitting Practices in Pennsylvania Municipalities."

are required to complete a Pennsylvania Natural Diversity Inventory (PNDI) Environmental Review and resolve any potential conflicts identified by this process with the associated state agency prior to submitting a permit application to the DEP.[220]

In 2007, the Pennsylvania Game Commission collaborated with the wind industry to create a Voluntary Wind Energy Cooperative Agreement to facilitate wind development while mitigating potential impact on wildlife.[221] Under the voluntary agreement, a participating developer is required to conduct at least one year of pre-construction surveys and two years of post-construction mortality monitoring at the proposed wind power site. These surveys can help avoid, minimize, or mitigate any potential adverse impacts of wind development on Pennsylvania wildlife.

Model ordinances

Model solar[222] and wind[223] zoning ordinances and a model solar permit[224] have been already developed for Pennsylvania. These model ordinances provide a base for moving towards greater consistency in renewable energy system siting and permitting regulation in Pennsylvania and should be updated periodically to reflect evolving best practices and to incorporate advances in technology while continuing to recognize public health, safety, environmental, and other policy goals. The biggest challenge remains proliferating their adoption across all local jurisdictions. Again, this proliferation does not necessarily dictate that all local requirements be uniform. Model ordinances cannot address every unique circumstance or local goal, but they can serve as a solid foundation for the adoption of fair, well informed local ordinances and can be adapted as necessary to suit local needs.

Siting best practices

Zoning ordinances can clarify which types of renewable energy system development are allowed in which areas and any restrictions that pertain to specific types of development. The American Planning

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[220] PA DEP. "Wind Energy." Accessed May 26, 2016. www.dep.pa.gov/Business/Energy/Wind/Pages/default.aspx#.V0da25MrKL4.

[221] Pennsylvania Game Commission. 2011. *Wind Energy Voluntary Cooperation Agreement: Second Summary Report.* www.batsandwind.org/pdf/Librandi-Mumma_PGC%202011_Vol%20Coop%20Agreement%202nd%20Summary%20Report.pdf.

[222] Environmental Planning & Design, LLC. 2012."Western Pennsylvania Rooftop Solar Challenge Model Ordinance for On-Site Usage of Solar Photovoltaic Systems." *Solar Installation Guidebook*. Accessed May 26, 2016. www.pennfuture.org/sunshot/sunshot_guide.pdf.

[223] PA DEP, Model Ordinance for Wind Energy Facilities.

[224] Environmental Planning & Design, Western Pennsylvania Rooftop Solar Challenge Model Ordinance.

Association has developed resources on wind and solar planning, zoning, and permitting issues for local governments.[225,226]

Planning

Local government planning can include goals for growing renewable energy and action steps to realizing its clean energy goals through changes to zoning ordinances. Additionally, site planning guidelines and smart building codes can encourage renewable energy development by designing buildings to ensure they allow for renewable energy development. For example, guidelines can promote lot and building orientation so that solar energy access is maximized and can include solar-ready building standards to ensure rooftop suitability for a future solar energy system.

Clear standards

Clarifying how renewable energy systems are treated in existing zoning ordinances can eliminate regulatory ambiguity and provide clarity to developers. Clear standards define the various types of renewable energy systems and in what zoning districts they are permitted; identify any mitigation of potential associated nuisances including visual impacts, noise, and encroachment; specify whether renewable energy systems will be allowed as a primary or accessory use in each zoning district; provide height, lot coverage, setback, fencing, screening, and noise requirements; and include relevant development standards like screening requirements or placement.[227]

Accessory use

Zoning ordinances can indicate that rooftop solar or small wind energy systems are permitted as an accessory use in both residential and nonresidential districts, subject to reasonable development standards including height restrictions. The designation as an accessory use can prevent inappropriate regulatory burdens on developers so long as certain development standards are met. An accessory use designation for small renewable energy systems is favorable because it denotes a permitted use that does not involve additional zoning decisions.

Primary use

Since large-scale renewable energy systems have different impacts on land use and can present other concerns, like impervious surface coverage, tree and habitat loss, transmission infrastructure, construction impacts, noise, glare, aviation impacts, and wildlife impacts, land-use codes can specify where this type of development is permitted and what mitigation of potential nuisances is required. Because of the impacts associated with large-scale renewable energy systems, local governments may

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[225] American Planning Association. 2011. *Planning for Wind Energy.* Accessed August 25, 2016. www.planning-org-uploaded-media.s3.amazonaws.com/legacy_resources/research/wind/pdf/pas566.pdf.

[226] American Planning Association. 2013. *Planning for Solar Energy Briefing Papers*. Accessed May 31, 2016. www.planning-org-uploaded-media.s3.amazonaws.com/legacy_resources/research/solar/briefingpapers/pdf/solarpaperscompendium.pdf.

[227] American Planning Association, Planning for Solar Energy Briefing Papers.

wish to restrict their location to certain districts (e.g., a large-scale wind farm might not be appropriate in the middle of downtown, or a community may wish to restrict visible solar arrays on historic buildings) or specifically encourage it in others. For example, the City of Erie allows urban solar farms without special permits in certain industrial and manufacturing zones and allows solar farms by conditional use in other districts.[228]

Transparency regarding application requirements, the appeals processes for the developer and stakeholders, and the review criteria—combined with a stepwise development process that indicates the time in each phase and the successive step if the project meets or fails to meet that step's requirement together—can ensure procedural clarity for developers and avoid additional staff time answering questions.

Incentives

On-site renewable energy systems can be added to currently in-place lists of development amenities that are eligible for obtaining density or floor area ratio bonuses. These are tools that encourage developers to provide a public benefit or amenity in exchange for allowing higher densities or floor area ratios than would otherwise be permissible. Municipal green building programs and policies can also incorporate on-site renewable energy systems as eligible building improvements to meet a green building standard or certification.

Solar easements, access permits, fences, and rights

As there is no federal property right to sunlight, states and local jurisdictions can develop their own solar easement, access permit, fencing, and rights laws or ordinances to provide a guarantee to a solar energy system owner access to solar light.[229]

A solar easement is a voluntary, negotiated agreement between the property owner developing a solar energy system and the adjacent property owner and is typically recorded with the necessary authority.

Solar access ordinances ensure that a solar energy system will not be shaded by a subsequent development or vegetation from an adjacent property by having the property owner with the solar system apply for a permit protecting the system from shading.

A solar fence delineates an area for a lot where solar light must fall unobstructed from neighboring property structures or vegetation.

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[228] City of Erie. Update 2010. Zoning Ordinance: 305.54 et seq. Accessed June 7, 2016. www.erie.pa.us/Portals/0/Content/Ordinances/Zoning/Zoning%20Ordinances%20(updated%202010-02-03).pdf.

[229] US DOE. 2011. "Solar Access and Solar Rights Laws." *Solar Powering Your Community: A Guide for Local Governments*. Accessed May 31, 2016. www.my.solarroadmap.com/userfiles/Resource-Section_Overview-of-Solar-Access-and-Solar-Rights.pdf.

A solar rights law prohibits local ordinances, neighborhood covenants, and bylaws from restricting solar energy system installation, generally with the caveat that restrictions are permitted where they are necessary to protect public health and safety, or do not unreasonably increase the cost or decrease the efficiency of a system.

Permitting best practices

IREC has created several guidance documents on rooftop solar PV permitting best practices.[230,231] The following subsections summarize its key recommendations and generalize them to the extent possible to include other renewable energy resources and larger nonresidential systems. While not all of these best practices are equally relevant to more complicated industrial renewable energy developments, they exhibit a general theme of enhancing transparency and increasing the efficiency of the permitting process through improvements that do not undermine the protective nature of permitting. As previously noted, extensive guidance on planning for and permitting larger industrial solar and wind energy facilities that are less amenable to standardized processes is available from the American Planning Association.

Post requirements online

A dedicated renewable energy permitting webpage for the municipality that offers a one-stop shop to find information on the local permitting process, including information on forms, fees, and inspections provides clear and transparent information to developers and other interested parties. Providing permitting information, application forms, procedures, and even a guide to siting and permitting renewable energy systems in the area on a dedicated webpage improves access to information and saves government employees time by reducing customer inquiries or application errors. For example, Philadelphia provides a solar guidebook on its website that includes a section on solar installation process codes and regulations as well as more general information to residents interested in going solar.[232]

Expedite the permit process for certain systems

Local governments can develop clearly defined review requirements that allow renewable energy systems meeting specific requirements (e.g., small residential solar systems) to be eligible for an

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230 IREC and The Vote Solar Initiative. 2013. "Simplifying the Solar Permitting Process: Residential Solar Permitting Best Practices Explained." Accessed May 31, 2016. www.irecusa.org/wp-content/uploads/2013/09/expanded-best-practices.pdf.

231 IREC. 2012. *Sharing Success: Emerging Approaches to Efficient Rooftop Solar Permitting*. Accessed May 31, 2016. www.irecusa.org/publications/sharing-success/.

232 City of Philadelphia. 2011. *Guidebook for Solar Photovoltaic Projects in Philadelphia [2nd Ed.].* Solar America Cities. www.phila.gov/green/PDFs/PhillySolarGuidebookFinal.pdf.

expedited process for having their permit reviewed and approved. This helps to avoid long delays and unnecessary studies.

Enable online permitting process

A permitting process that provides for permit submittal, review, and approval streamlines the permitting process, saves municipal and developer staff time, and can allow municipal staff an efficient mechanism for tracking permits as they move through a system of review entailing multiple levels of review.

Charge fair permitting fees

Pennsylvania municipalities can adopt a flat, cost-based fee structure in lieu of the more common value-based fee structure widely used today. In a cost-based fee structure, permitting fees are based on the cost to review and approve the permit, whereas value-based fees can vary by the system cost or size and might not appropriately reflect the actual cost (i.e., staff time) to review the permit. Keeping a flat fee structure, especially for smaller renewable energy systems, provides additional simplicity that can helps installers. In some cases, permit fees can be waived to further induce specific types of renewable energy development. For example, waiving or reducing permitting fees related to renewable energy projects sited on brownfields, mines, or landfills can help reduce the costs of siting on land that might not be suitable for other types of redevelopment.

Provide a fast turnaround time

Same-day permit approval for smaller renewable energy systems like residential rooftop solar systems and defined, streamlined timelines for other renewable energy systems minimizes the resources spent on visits to municipal departments overseeing permitting and avoids bottlenecks in renewable energy system deployment.

Avoid community-specific licenses

Statewide and nationwide uniformity on licensing requirements simplifies the time and expense of developers operating in multiple jurisdictions. For example, the North American Board of Certified Energy Practitioners PV installer certification could be a requirement adopted by a local government in lieu of a unique local license for local installers.

Ensure a narrow inspection appointment window

When on-site inspections are necessary, a narrow appointment window (two hours or less) minimizes installer waiting time as well as making it more likely the installer will be ready when the inspector arrives onsite. Online inspection scheduling, including features like an email reminder prior to a scheduled appointment, can provide additional benefits.

Eliminate excessive inspections

While the issuance of a permit typically allows the developer or installer to begin installing the system, the completed system must pass all inspections to gain final approval. To the extent possible, minimizing the number of separate local government inspections—for example, by combining electrical, structural, and fire safety inspections for small rooftop solar systems—can save time while still accomplishing important local government permitting objectives. Coordinating utility interconnection inspections with local government permitting inspections can be more difficult but can provide additional efficiency and time-savings for developers.

Train permitting staff

Municipalities can train permitting staff so they are aware in advance of how to review permits for compliance with relevant laws. The state government can provide additional support by offering information and training to local government permitting staff regarding state-developed model ordinances, available permitting tools, and technical assistance.

State-led approaches

Although local governments currently retain control on most siting and permitting issues, the Pennsylvania state government can implement several policies to help advance best practices. First, Pennsylvania can establish renewable energy development as a chief priority in its state energy plan. The state energy plan can be used to develop legislation and regulation that advances renewable energy development and encourages local governments to adopt siting and permitting model ordinances.

The state can also develop resources to encourage siting and permitting renewable energy resources in desirable locations. A comprehensive website on siting and permitting in Pennsylvania could offer a detailed overview of the process to potential developers and include resources like online maps, an application portal that local governments could elect to adopt, access to key state and local data, interactive planning tools, information for local governments, additional resources for developers, and contact information to request technical assistance.

Establishing renewable energy development as a goal and encouraging local governments to adopt best practices may not be sufficient to overcome persistent barriers in siting and permitting that permeate across the patchwork of local government regulation in place today. Therefore, state leaders may consider mechanisms that implicate more direct siting and permitting involvement. The level of involvement could in theory be broad or narrow. On the narrow end for example, Pennsylvania can adopt limits on local solar PV permitting fees, capping fees at the local government's actual costs to review the permit or a specific upper bound for the maximum amount that can be charged for a permit. For example, the Colorado Fair Permit Act prevents local jurisdictions from charging fees that exceed the lessor of the actual cost to issue the permit or $500 for a residential system or $1000 for a nonresidential system.[233] Another option with respect to permitting fees could be to employ the system now used in Philadelphia, which has adopted a permitting fee of $25 per $1,000 of installation *labor costs* rather than the regular fee of $25 per $1,000 of *equipment and labor* costs for rooftop solar PV systems. Philadelphia also employs a streamlined review process which does not include an application fee for systems that meet certain standards.[234]

On the broader end of the scale, several states have adopted statewide permitting processes for renewable energy facilities such as commercial wind farms, and in several of these states (e.g., Ohio, Vermont, and Washington) statewide rules are used for most new electric generation facilities.[235] While there could be some benefits to this approach, such as greater access to expertise and resources that ensure a thorough review, we do not recommend it because reducing local government control over zoning and permitting can have contentious and concerning implications. In light of concerns raised by the surrender of local land-use control, a more refined approach that focuses on removing administrative inefficiencies, state facilitation rather than state control, and retention of local decision-making authority could be adopted. For instance, efficiencies might be gained by allowing local officials to agree to a consolidated, state-facilitated process for projects that involve multiple local agencies. Or, local authorities may be given the option to seek assistance and resources from a state siting agency, and at their election, be permitted to voluntarily surrender some elements of siting control and review to that agency. These options might be exercised in instances where local officials do not believe they have the expertise or resources to properly evaluate project impacts. There could be any number of variations on this theme of providing local officials with the resources they need to make sound judgments, while at the same time retaining local authority and facilitating the siting of renewable energy projects.

Taking advantage of under-utilized lands

A dramatic expansion of renewable generation in Pennsylvania will undoubtedly affect the character and appearance of many local areas. While these impacts may be minimal in the case of rooftop solar generation, the development of utility-scale renewables such as wind and solar farms will be visible even with responsible siting and permitting regulations. This may result in land-use changes that some residents consider to be detrimental. However, the effects of land-use changes can be neutral or resoundingly positive in instances where development takes advantage of lands that are unsuitable or under-utilized for other types of development. In other words, in the same way that rooftop solar can be less impactful because it takes advantage of the already built environment, some utility-scale projects can be made less impactful by siting them on land that cannot be utilized for other purposes.

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[233] IREC, Sharing Success.

[234] City of Philadelphia, Guidebook for Solar PV.

[235] Environmental Law Institute. 2011. *State Enabling Legislation for Commercial Scale Wind Power Siting and the Local Government Role*.

Landfills and brownfields are two varieties of typically under-utilized land that can serve to host utility scale renewable energy projects without invoking criticisms often levied against projects sited in the un-built environment (e.g., agricultural lands, rural undeveloped land). The U.S. Environmental Protection Agency (EPA) has conducted an analysis of renewable energy potential on landfills and brownfields in each state, showing that the potential scale for development is immense. EPA estimates that Pennsylvania landfills and brownfields could host almost 46,000 MW of utility-scale solar generation in project sizes ranging from 0.3 megawatts (MW) to more than 3,000 MW. The list of sites numbers in the thousands, including major contaminated lands within the Superfund program, hundreds of landfills, and hundreds of abandoned coal mines.[236] While this estimate involves a series of assumptions and could overstate what can feasibly be built on these lands, the potential for large-scale development is considerable.

There are, however, challenges associated with landfill and brownfield renewable energy development. For landfills, permitting and technical engineering requirements are typically more complex than with other lands because the characteristics of the sites are unique (e.g., weight limits, landfill caps, distance to interconnection, ongoing operations). Contaminated lands may involve similar complexities, along with heightened concerns about potential liability for the clean-up of contaminants. Developers may shy away from projects on these types of land due to the complexity and uncertainties involved, despite the otherwise favorable characteristics.

Thus, while the potential for using under-utilized land for renewable energy development in Pennsylvania is considerable, realizing that potential will take a concerted effort on the part of the state to facilitate the process. This facilitation should include: developing guidance to help potential developers navigate the process, applicable laws, and restrictions; assisting with coordination among the various local and state agencies that may be involved; and providing incentives that steer development towards under-utilized lands as a balance to the enhanced risks and potential costs involved. It can be accomplished by utilizing existing state programs oriented around redevelopment and customizing them to more effectively support the state's goals for in-state renewable generation.

Incentives to fossil fuel-based energy

Renewable energy is often criticized by its detractors as costly and uncompetitive with fossil fuels. While it is true that subsidies have played a prominent role in helping grow the nascent renewable energy industry, it is also true that a variety of subsidies have historically been available to the fossil fuel industry for much the same purpose. Many of these subsidies for fossil fuels remain deeply embedded in a variety of state laws, despite the fact that the fossil fuel industry is unarguably now "mature." Moreover, in spite of ever-increasing knowledge and understanding of the negative consequences associated with continued use of fossil fuels, the costs of these consequences to society are frequently not covered by the industries extracting, transporting and/or utilizing the fossil fuels; nor are these costs

[236] US EPA. *Repowering America's Land Screening Dataset.* Accessed June 8, 2016. www.epa.gov/re-powering/re-powering-mapping-and-screening-tools.

included in the price to the average consumer. The playing field between renewables and fossil fuels is decidedly skewed, making fossil fuels appear to be lower cost than they actually are, or on the other side of the coin, making renewable energy appear relatively more expensive.

Leveling the playing field

This report focuses on eliminating fossil fuel *use*, from an end-use perspective, in Pennsylvania. However, the rationale for eliminating fossil fuel use includes avoiding the detrimental effects that the extraction of these resources has on Pennsylvania, as well as those attributable to the use of fossil fuels within Pennsylvania to serve end uses in other states (e.g., the generation of electricity).

In recognition of this fact, this subsection first provides an overview of some of the current advantages enjoyed by the fossil fuel industry in Pennsylvania in the form of financial incentives that support fossil fuel extraction and consumer use. These financial incentives collectively offer considerable subsidies to fossil fuel resources, many of which are not or cannot be utilized by renewables (e.g., fuel tax exemptions do not benefit technologies like renewables that do not have fuel costs).[237]

The next subsection discusses measures that the state could employ to affect the demand for fossil fuels in the electricity generation sector, and briefly addresses restrictions on oil and natural gas development in particular. These policies are referred to collectively as mechanisms for slowing or eliminating the development of fossil fuel infrastructure in the interest of protecting the general health and well-being of Pennsylvania citizens. Avoiding and/or internalizing the negative externalities of fossil fuel extraction and use would have the effect of leveling the playing field between fossil fuels and renewables that do not carry these same risks.

Financial incentives

An analysis by PennFuture estimates that Pennsylvania paid more than $3.2 billion in fossil fuel subsidies during fiscal year 2012–2013. The largest portion of subsidies ($2.27 billion) is awarded to end users (Table 13), and most subsidies are in the form of tax breaks. In addition to the tax incentives, Pennsylvania supports fossil fuels through legacy funds and economic development programs, not valued through the PennFuture study.[238]

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[237] Readers should note that we address only direct financial incentives here, rather than other forms of “incentive” such as regulatory exemptions or exclusions.

[238] PennFuture, 2015 Fossil Fuel Subsidy Report.

Table 13: Fossil fuel subsidy by fuel cycle

Fuel Cycle	Subsidy
Extraction and Production	$618,000,000
Processing	$235,778,000
Transportation	$131,448,000
End Use	$2,271,267,000
Remediation	Not calculated
Total	**$3,256,493,000**

Source: PennFuture 2015 Fossil Fuel Subsidy Report.

Tax incentives for fossil fuels include the following exemptions and credits:

***Sales and use tax exemptions*.** Pennsylvania charges a 6 percent sales tax, and a complementary use tax on goods where the sales tax is not paid at the point of sale. Exemptions are provided for certain transactions, including the purchase or use of coal, certain fuels including electricity, steam, gases, and fuel oils for residential use. Gasoline and motor fuels are also exempt from sales and use taxes, but are substituted with other taxes. Other exemptions include agricultural equipment, commercial vessel supplies (including fuel, equipment, ships, cleaning, and maintenance supplies), manufacturing equipment (including parts and supplies), parts and supplies used by public utilities, certain drilling costs, and rail transportation equipment.[239,240]

Fuel tax exemptions for fuels purchased by federal and state governments, nonprofits, private schools, volunteer emergency vehicles, second-class county port authorities, electric cooperatives, and foreign diplomats. Fuel purchases for use in certain agricultural and farm equipment, buses, and truck refrigeration are also exempt, and fuel distributors are granted discounts.[241]

Realty transfer tax exemptions are levied on the value of any interest in real estate transferred by deed. Leases for the production or extraction of coal, oil, natural gas, or minerals are exempt from the realty transfer tax.[242]

Local property tax exemptions for oil and gas reserves and operating wells.[243]

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[239] PennFuture, 2015 Fossil Fuel Subsidy Report.

[240] The use of sales tax incentives to support fuel switching was also discussed on pages 11-12 of the *Electrifying Space Heating, Water Heating, and Other End-Uses in Pennsylvania* in the context of measures to support electrification of end uses, primarily the use of natural gas for space and water heating.

[241] PennFuture, 2015 Fossil Fuel Subsidy Report, 33-36.

[242] PennFuture, 2015 Fossil Fuel Subsidy Report, 30.

[243] PennFuture, 2015 Fossil Fuel Subsidy Report, 30-31.

Motor carrier road tax exemptions for political subdivisions, emergency vehicles, charitable and religious organizations, schools buses, electric cooperatives, and recreational vehicles.[244]

Alternative energy production tax credit, which provides tax credits to both renewable energy and certain coal projects.[245]

Pennsylvania resource manufacturing tax credit, which provides tax credits for certain entities purchasing ethane for use in ethylene manufacturing facilities.[246,247]

***Capital stock and franchise tax exemptions*.** Corporations engaged in manufacturing, processing, or research, that purchase pollution control equipment were exempt from these taxes; however, both of these taxes were phased out for all companies in 2016.[248,249]

- ***Gross receipts tax exemptions*.** Certain gross receipts of municipally owned utilities and all gross receipts of electric cooperatives and natural gas companies are exempt from the gross receipts tax.[250]
- ***Public utility realty tax and exemptions***, used to tax utility property in place of local real estate taxes. Utility easements, railroad rights-of-ways, and municipal utilities are exempt from the Public Utility Realty Tax. Electric generation facilities are taxed under local real estate tax instead of the Public Utility Realty Tax.[251] However, the Pennsylvania courts have decided that certain portions of electricity generating property are commercial and industrial equipment that are exempt from personal property taxes.[252]

In order to allow renewables to more fairly compete and to fund the programs needed to move the state to 100 percent renewables, these tax incentives should be phased out or scaled back. In some cases, a prioritization and careful consideration of the unintended impacts will be necessary in order to achieve other goals. For instance, eliminating a sales tax exemption for residential electricity purchases

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[244] PennFuture, 2015 Fossil Fuel Subsidy Report, 37-39.

[245] PennFuture, 2015 Fossil Fuel Subsidy Report, 13-14.

[246] PennFuture, 2015 Fossil Fuel Subsidy Report, 14.

[247] As described in Section 5.4 discussing the industrial use of fossil fuels, the chemical manufacturing industry, which uses significant quantities of fossil fuels as feedstock, is the single largest manufacturing category in Pennsylvania.

[248] Pennsylvania Department of Revenue. "Capital Stock and Foreign Franchise Taxes." Accessed May 31, 2016. www.revenue.pa.gov/GeneralTaxInformation/Tax%20Types%20and%20Information/Pages/Corporation%20Taxes/Capital%20Stock-Foreign%20Franchise/Capital%20Stock-Foreign%20Franchise%20Tax.aspx#.V0hXducrJN0.

[249] PennFuture, 2015 Fossil Fuel Subsidy Report, 15.

[250] PennFuture, 2015 Fossil Fuel Subsidy Report, 16-17.

[251] PennFuture, 2015 Fossil Fuel Subsidy Report, 18-20.

[252] Commonwealth of Pennsylvania. 2003. *Allegheny Energy Supply Company v. Greene County Board of Assessment Appeals*, 837 A.2d 665 (Pa.Cmwlth.2003). Last accessed May 31, 2016. www.caselaw.findlaw.com/pa-commonwealth-court/1452858.html

could be counterproductive from a standpoint of supporting electrification of residential end uses currently served by fossil fuels (e.g., home heating with natural gas or heating oil). Likewise, if Pennsylvania were to expressly exclude all electric generation equipment from the existing personal property exemption for commercial and industrial manufacturing equipment, it would be subjecting renewable energy facilities to additional taxes as well.

Policies to limit new fossil fuel infrastructure

In addition to making changes to the tax regimes that have supported the fossil fuel industry, Pennsylvania can limit emissions from fossil fuels and discourage further development of fossil fuel resources by implementing new or strengthening existing environmental and permitting regulations. New laws and regulations can be designed to affect the infrastructure that creates a demand for fossil fuels within the state, thereby reducing or eliminating the perceived need to increase in-state supply of fossil fuels (e.g., fracking for natural gas in particular). First and foremost, the state can work to develop and implement limitations on CO_2 emissions from power plants, as required under EPA's Clean Power Plan.[253] Gradually strengthening emissions standards will not only improve air quality and lessen climate impacts, but will also result in more favorable economics for renewable energy and energy efficiency.

This somewhat indirect path could be taken further by adopting state regulations for limiting new fossil fuel generating capacity, or through outright prohibitions on the development of new fossil fuel generating capacity. For instance, a state law might adopt stringent controls on local pollutant emissions to air or discharges to water; strictly control the handling, storage and disposal of produced waste materials; constrain locations to certain minimum distances from environmentally sensitive areas, population centers, or public lands; limit facility water use; or many other "public interest" type restrictions. Such restrictions, or even outright prohibitions on new fossil fuel development, are fully within a state's authority. While policies of this type may affect matters such as wholesale energy market regulation that fall within the jurisdiction of the FERC, the courts have affirmed that states may pursue policies regulating generation facilities without "direct interference" from the FERC. [254]

Demand modifying measures can and should be supported by enhanced regulation of fossil extraction activities in a manner that is consistent with protecting general health and safety, and complements the state's overall goal of reducing and eliminating greenhouse gas emissions. Such regulations are equally important, affecting the supply side of fossil fuel infrastructure within the state by removing regulatory exemptions and exclusions, or remedying a complete lack of regulations. Like direct financial incentives,

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[253] PennFuture. 2015. *A Fresh Start for Pennsylvania,* 11. www.pennfuture.org/UserFiles/PDFs/GovWolfPolicyRecommendations_201501.pdf.

[254] *Conn. Dep't of Pub. Util. Control v. FERC,* 569 F.3d 477, 481 (D.C. Cir. 2009), "State. . . authorities retain the right to forbid new entrants from providing new capacity, to require retirement of existing generators, to limit new construction to more expensive, environmentally-friendly units, or to take any other action in their role as regulators of generation facilities without direct interference from the Commission."

regulatory exclusions create tangible advantages for fossil fuels that often are not or cannot be enjoyed by the renewable energy industry, and as a consequence undermine its competitiveness.

Due to the complexity of the issues surrounding regulation of fossil extraction activities, this report does not attempt to provide recommendations for specific regulatory measures. However, at a high level, regulatory measures could include:

- Issuing a statewide moratorium or ban on shale gas extraction activities;
- Enhanced regulations on various activities associated with hydraulic fracturing (e.g., wastewater, stream impacts) and bans on any activities that cannot be rendered safe even under enhanced regulation;
- Additional standards for the construction and operation of pipelines and/or railroad transport of fossil fuels and fossil fuel products;
- Strengthening state methane emission standards for extraction sites and supply chains (in addition to federal standards).[255]
- Prohibition of waste containing toxic or hazardous properties that have the potential to negatively impact public health or the environment.

Policies of this type would directly support the state's climate and environmental goals. Of equal importance, they would also play a role in further leveling the playing field between renewable energy and fossil fuels, making fossil fuel development itself less attractive financially by internalizing the costs of avoiding negative environmental and social impacts in the price of the fuel.

[255] EPA began the process requiring oil and gas companies to control methane emissions from new sources in June 2016 through its authority under the federal Clean Air Act (40 CFR Part 60). Pennsylvania has adopted some controls, though they are not as extensive as those adopted in several other states (e.g., Colorado). *See* NREL. 2015. *Controlling Methane Emissions in the Natural Gas Sector: A Review of Federal & State Regulatory Frameworks Governing Production, Gathering, Processing, Transmission, and Distribution*. www.nrel.gov/docs/fy15osti/63416.pdf.

APPENDIX A: MODELING ASSUMPTIONS AND METHODOLOGY

This study includes modeling of two future scenarios of Pennsylvania's energy sector:

- Reference or Business-as-Usual: This scenario models the impacts of all state and federal statutes currently on the books and the most likely scenario of future energy prices and investments in energy infrastructure in a future in which no changes are made to these existing statutes or new regulations related to the demand for and supply of energy introduced.
- PA-100%-RE: In this scenario new regulations are introduced to cause sufficient changes in energy infrastructure investment to achieve supply of 100 percent of Pennsylvania's energy needs by renewables by 2050.

Overview of methodology

Both energy futures were modeled using Synapse's Multi-Sector Emissions Model (M-SEM) model and a version of the National Renewable Energy Laboratory's Regional Energy Deployment System (ReEDS) model adapted by Synapse.

M-SEM allows us to construct a reference case based on historical data and future projections at the state level. We use that reference case to test different shifts, policies, and cross-sector interactions for use in parallel with more detailed electricity sector modeling. In essence, the tool lets us compare apples to apples: First, it gives us calibrated common units for all sectors so that we can transparently synthesize data by end-use, by sector, by state, and by fuel type. With these results, we can tie historical data to future trends for energy use and resulting emissions.[256]

ReEDS is a long-term capacity expansion and dispatch model of the electric power system in the lower 48 states. It has a high level of renewable resource detail with many wind and solar resource regions, each with availability by resource class and unique grid connection costs. Synapse uses a version of ReEDS that we have adapted in house to provide detailed output reporting important for our other tools. Model outputs include generation, capacity, transmission expansion, capital and operating costs, water use, and emissions of CO_2, sulfur dioxide (SO_2), nitrogen oxides (NO_X), and mercury. The model operates through 2050 in two-year steps, with each two-year period divided into 17 time slices representing morning, afternoon, evening, and night in each of the four seasons, plus an additional summer peak time slice. ReEDS includes data on the existing fossil fuel facilities in each of the model's

[256] More information at: www.synapse-energy.com/MSEM.

134 Power Control Areas (PCAs). These 134 PCAs are contiguous with the lower 48 states. States are made up of between one and 11 PCAs.[257]

Modeling assumptions

Emission reductions were modeled as "shifts" from the Reference Case, which was designed to reflect compliance with the Clean Power Plan in all states. Synapse's Multi-Sector Emissions Model (M-SEM) reflects emission reductions state-wide for Pennsylvania electric, transportation, buildings, and industrial sectors. In addition, the electric sectors in both the Reference and PA-100%RE Cases were modeled using the National Renewable Energy Laboratory's (NREL) Regional Energy Deployment System (ReEDS) model.[258] ReEDS is a long-term capacity expansion and dispatch model of the electric power system in the lower 48 states. This appendix describes the Baseline modeling assumptions and methodology for this study.

Multi-Sector Emissions Model (M-SEM)

M-SEM is a purpose-built Excel model that allow us to construct a business-as-usual case based on historical data and future projections at the state and regional level. We used that reference case to test different shifts, policies, and cross-sector interactions for use in parallel with more detailed electricity sector modeling. In essence, the tool let us compare apples to apples: First, it gives us calibrated common units for all sectors so that we can transparently synthesize data by end-use, by sector, by state, and by fuel type. With these results, we can tie historical data to future trends for energy use and resulting emissions.[259]

Electric sector ReEDS model

Synapse used an in-house version of the NREL's ReEDS model adapted to allow for more detailed outputs by state and sector, and to permit differentiation of energy efficiency expectations by state. Spreadsheet model electric sector results are calibrated to match the more detailed and rigorous ReEDS outputs so that we can verify the impact on electric sector generation and emissions in both the Baseline and PA-100%RE Cases.[260] This analysis is not limited to Pennsylvania—we modeled the entire country in order to understand the implications economic imports and exports of energy from the state, as well as the availability of Renewable Energy Credits (RECs) for its Renewable Portfolio Standard (RPS) compliance.

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[257] More information at: www.nrel.gov/docs/fy12osti/46534.pdf.

[258] More information at: www.nrel.gov/analysis/reeds.

[259] More information at: www.synapse-energy.com/MSEM.

[260] More information at: www.nrel.gov/analysis/reeds.

In the Reference Case, compliance with the Clean Power Plan was modeled as all states achieving the state-level mass-based targets during interim (2022-2029) and final (2030) periods that include estimated emissions from new sources (the "new source complement"). Our modeling assumed initially freely allocated allowances, followed by allowances being purchased at an auction at the marginal price of CO_2 ($/ton), and the revenues recycled back to the states based on their caps.

Temporal scope

The time period of this analysis is the years 2015-2050. In the initial modeling steps, modeling was performed at five-year intervals but presented for Years 2020, 2030, 2040 and 2050 in the final report. In using ReEDS, modeling was performed at two-year intervals starting in 2014. Historical data through 1990 was included in the spreadsheet model to serve as a point of comparison for future emission reductions.

Geographic scope

Synapse focused its "shift" analysis in the state of Pennsylvania. In the ReEDS model, all states in the continental United States are represented. ReEDS divides the United States into 134 power control areas that are consistent with state boundaries and can be aggregated to model state impacts. Each power control area is modeled as having aggregated "units" of each resource type, the size of which is equal to the sum of the capacities of similar units in that territory. For this analysis, Synapse modeled the country as a whole to capture interactions between states and provided outputs for Pennsylvania.

Caveats and data limitations

When evaluating scenarios over very long timeframes in ReEDS, it is important to remember that key inputs were forecasted (e.g., loads, fuel prices, and resource costs) over a 35-year period from 2015 to 2050. Over at least the latter half of this period, these forecasts and the modeling results should be treated as highly uncertain.

In Synapse's modeling work, several key aspects of these scenarios were developed "exogenously" and entered into the model as inputs. These assumptions include:

- Energy efficiency trajectory
- Rooftop PV market penetration
- EV penetration (although the model can choose how and when to utilize EVs as storage)

- Environmental costs at coal plants, which are based on Synapse's Coal Asset Valuation Tool (CAVT)[261]

Synapse developed the assumptions that change the levels of these resources across different scenarios. ReEDS does not optimize for costs associated with the items identified above, beyond a simplified representation of the Clean Air Interstate Rule governing SO_2 emissions impacting coal plant environmental costs. Instead, these costs are added in post-processing analysis.

For this analysis, we took ReEDS system costs by technology, control area, and year as raw outputs from the model and feed them through RePRT before use and comparison across scenarios. RePRT is a Synapse-built post-processing tool that translates ReEDS outputs into annualized total cost to the system by technology and control area. For fixed operations and maintenance (O&M) charges and fuel costs, the tool simply pulls outputs straight from ReEDS. For capital costs for new technologies, however, the tool calculates and adds interest during construction to the capital cost outputs from ReEDS, and then amortizes those costs over a technology-specific investment life. The tool processes capacity, generation, and emissions outputs from ReEDS into a form that allows Synapse to easily parse, aggregate, and present results at various resolutions.

Sales and energy efficiency

Annual retail electric sales were projected using state-specific EIA historical data and regional growth rates from the Annual Energy Outlook (AEO) 2015 reference case. On average, the AEO 2015 reference case assumes an annual growth rate of about 0.3 percent per year for the region that includes Pennsylvania. From this we "backed out" the AEO representation of ongoing savings—estimated at 0.48 percent of 2012 sales—from new energy efficiency measures and replace it with more detailed forecasts.[262] Under the reference case, we assumed a 1 percent annual incremental savings rate from energy efficiency in Pennsylvania. The PA-100%RE case increases this to 3 percent annual incremental savings.

Renewable energy

Our modeling incorporated all on the books RPSs throughout the United States that require utilities to procure a percentage of their electric retail sales in qualified forms of renewable generation. In Pennsylvania, this includes the current target of 18 percent by 2020, held flat afterwards. This is equivalent to a 6.0 percent wind/water/solar resource standard that applies to 97 percent of state sales. This downward target adjustment reflects that the current standard permits some non-renewable

[261] Knight, P., J. Daniel. 2015. *Forecasting Coal Unit Competitiveness: Coal Retirement Assessment Using Synapse's Coal Asset Valuation Tool (CAVT).* Synapse Energy Economics. www.synapse-energy.com/sites/default/files/Forecasting-Coal-Unit-Competitiveness-14-021.pdf.

[262] White, D., et al. 2013 Update. *State Energy Efficiency Embedded in Annual Energy Outlook Forecasts*. Synapse Energy Economics. www.synapse-energy.com/sites/default/files/SynapseReport.2013-11.0.EE-in-AEO-2013.12-094-Update_0.pdf.

resources to qualify, and the 97 percent share of sales reflects the fact that the target does not currently apply to municipal and cooperative utilities. The share of renewables required and types of resources acceptable for classification as renewable varies from state to state.

Under the PA-100%RE scenario, Pennsylvania utilities must generate a minimum amount of renewable energy in state—additional compliance could come from purchase of RECS from out of state. There is no requirement for Pennsylvania to sell RECS outside to other states.

Solar power

We assumed cost reduction trajectories for utility and rooftop solar PV based on the NREL's SunShot Vision study, which describes significant cost reductions from baseline levels by 2020. We assumed costs decline 62.5 percent from 2010 levels by 2020, and 75 percent by 2030 reaching $1.00 per watt installed for utility scale installations in 2030. While module costs have been well below $1.00 per watt in recent years, the many other costs to permit and construct a solar plant ("soft costs") have persistently kept realized costs higher.

ReEDS is a supply-side-only model: it does not optimize the decisions end users would make to install rooftop PV systems. These were input into the model based on a separate tool NREL developed for its SunShot analysis. NREL's dSolar model forecasts customer adoption of rooftop solar PV for residential, commercial, and industrial customers, with a high degree of spatial resolution.[263] Nationally, approximately 8 GW of rooftop PV is installed today. In the Reference scenario, we assumed each state's current net metering laws remain in place. Once a state reaches its net metering cap, generating in excess of a customer's load is compensated at the wholesale rate. Nationally, this leads to a buildout of 17 GW by 2020, 83 GW by 2030, and 245 GW by 2050. In Pennsylvania, this translates to 440 MW by 2020, 2,200 MW by 2030, and 7,100 MW by 2050.

In the PA-100%RE case, we assumed 650MW of customer sited PV by 2020, 8,000 MW by 2030, and 25,000 MW by 2050.

In the Reference case, ReEDS builds new utility PV installations based on economics. In order to meet the ambitious goals in the PA-100%RE case, we assigned a minimum level of utility scale PV installations at 300 MW by 2020, 4,000 MW by 2030, and 25,000 MW by 2050.

Wind

Wind supply curves are defined for 356 regions in ReEDS—12 in Pennsylvania—each with a specified capacity potential in each wind Class 3 through 7. The potential for new wind is based on modeling by AWS Truepower using the Mesomap® process. Results were processed to exclude areas such as urban areas, federally protected lands, and onshore water features. Our costs for land-based wind are based

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[263] Sigrin, B., M. Gleason, R. Preus, I. Baring-Gould, and R. Margolis. 2016. *The Distributed Generation Market Demand Model* (dGen): Documentation. NREL/TP-6A20-65231. Golden, CO: National Renewable Energy Laboratory.

on research done for the Department of Energy's recent *Wind Vision Report*.[264] Base wind costs in 2015 range from $1,759 per kW for projects in Class 3 areas to $1,641 per kW for projects in Class 7. This represents the turbine itself—ReEDS adds interconnection costs to the regional transmission system based on a detailed geographic analysis of wind resources.

The *Wind Vision Report* assumes cost reductions and capacity factor increases over time for land-based wind. In this analysis, we held base costs for land-based wind constant over the study period at the levels cited above, but we used the increasing capacity factors from the *Wind Vision.* Possible land-based capacity factors range from 35 to 49 percent in 2020 and range from 38 to 58 percent in 2040.

Offshore wind costs are also taken from the *Wind Vision* assumptions, in which costs are forecast to fall over time. Base overnight costs for shallow offshore wind resources in 2020 are $4,471 per kW in Class 3 areas and $4,052 for projects in all other areas. These costs fall by roughly 30 percent over the study period. Fixed O&M for shallow offshore wind is $109 per kW-year in 2020, falling to $94 per kW-year in 2040. Possible offshore capacity factors range from 35 percent to 48 percent in 2020 and 40 percent to 54 percent in 2040. The model also characterizes deep offshore resources, available when the supply of cheaper shallow resources has been exhausted. Full documentation of these assumptions is available in the *Wind Vision* study.

In the Reference case, ReEDS builds new wind installations based on economics. In order to meet the ambitious goals in the PA-100%RE case, we assigned a minimum level of wind installations at 1,700 MW by 2020, 5,000 MW by 2030, and 8,500 MW by 2050.

Natural gas prices

Synapse used natural gas prices as a simple average of the AEO 2015 "Reference" and "High Oil and Gas" scenarios. Figure 49 presents the projected price of natural gas at the Henry Hub under these assumptions. AEO 2015, released in April 2015, did not accurately reflect persistently low natural gas prices, and at the time of modeling, indications were that the AEO 2016 forecast would be substantially lower.[265] As a result, we combined the AEO 2015 Reference and High Oil and Gas Supply cases to develop a lower long-term forecast. Note that the ReEDS model used for validating the electricity sector shifts uses natural gas prices based on an endogenous supply-curve formulation, in which cost is a function of the quantity demanded with underlying supply curves calibrated to AEO reference case data; Synapse verified that a consistent natural gas price is used between ReEDS and the all-sector Excel model.

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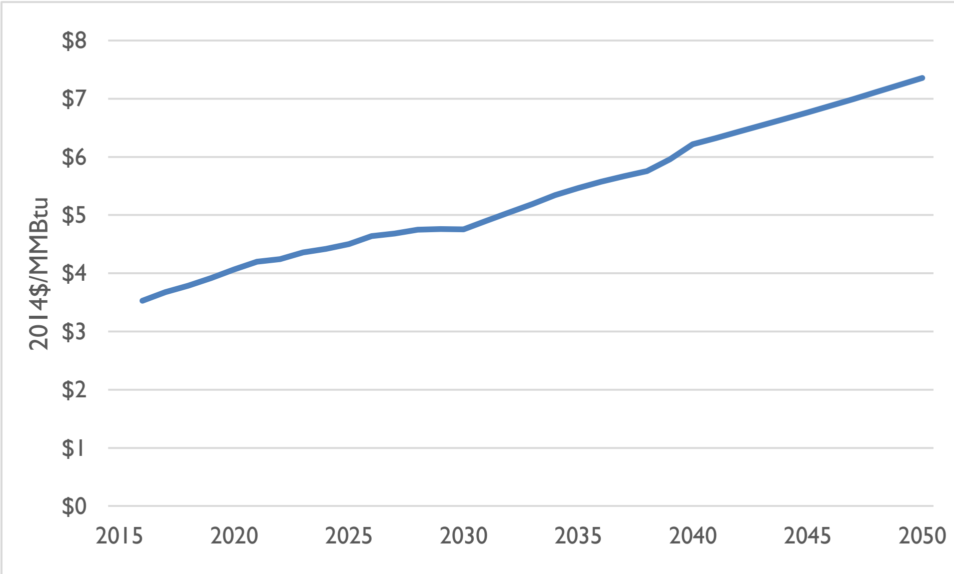
[264] US DOE. 2015. *Wind Vision Report*. Accessed June 22, 2015. Available at: www.energy.gov/eere/wind/wind-vision.

[265] This assumption proved true: for example, the national average 2030 price of natural gas delivered to electric generators in the AEO 2016 Reference case was $5.57 per MMBtu (in 2015 dollars) compared to $6.44 per MMBtu (in 2015 dollars) for the same variable in the AEO 2015 Reference case, a reduction of 14 percent.

Figure 49. Henry Hub Natural Gas Price, average of AEO 2015 Reference and High Oil & Gas Supply cases



Source: AEO 2015, Table 13.

Recent and near-term unit additions

A number of new natural gas units have been announced for the PJM states in 2015 and 2016. A list of these units is presented in Table 14, and includes a summary of the state in which the units are coming online, the associated plant and utility, and each unit's capacity, anticipated in-service year, and generation technology. This list was developed using unit additions reported in the 2014 edition of the EIA 860 database of generators currently under construction. In total, this includes 1,762 MW of new natural gas units in Pennsylvania in 2015 and 2016.

Table 14. PJM recent and expected unit additions

State	ISO	Plant	Utility	Nameplate Capacity (MW)	First Year of Operation	Fuel Type	Unit Type
DC	PJM	DC Water CHP	DC Water	4.7	2015	Biomass	GT
DC	PJM	DC Water CHP	DC Water	4.7	2015	Biomass	GT
DC	PJM	DC Water CHP	DC Water	4.7	2015	Biomass	GT
DE	PJM	DD Hay Road Solar 23 LLC	Laurel Capital Partners	1.2	2015	Solar	PV
DE	PJM	Garrison Energy Center LLC	Garrison Energy Center LLC	235	2015	Natural Gas	CT
DE	PJM	Garrison Energy Center LLC	Garrison Energy Center LLC	126	2015	Natural Gas	CA
IL	PJM	Elwood Energy Storage Center	West Chicago Battery Storage LLC	19.8	2015	Storage	BA
IL	PJM	Grand Ridge Battery Projects	Invenergy Services LLC	31.5	2015	Storage	BA

State	ISO	Plant	Utility	Nameplate Capacity (MW)	First Year of Operation	Fuel Type	Unit Type
IL	PJM	Jake Energy Storage Center	Joliet Battery Storage LLC	19.8	2015	Storage	BA
IL	PJM	Nelson Energy Center	Invenergy Services LLC	181.9	2015	Natural Gas	CT
IL	PJM	Nelson Energy Center	Invenergy Services LLC	179.4	2015	Natural Gas	CT
IL	PJM	Nelson Energy Center	Invenergy Services LLC	133.5	2015	Natural Gas	CA
IL	PJM	Nelson Energy Center	Invenergy Services LLC	133.5	2015	Natural Gas	CA
IL	PJM	Orchard Hills Renewable Energy Station	Hoosier Energy R E C, Inc	2.7	2016	LFG	IC
IL	PJM	Orchard Hills Renewable Energy Station	Hoosier Energy R E C, Inc	2.7	2016	LFG	IC
IL	PJM	Orchard Hills Renewable Energy Station	Hoosier Energy R E C, Inc	2.7	2016	LFG	IC
IL	PJM	Orchard Hills Renewable Energy Station	Hoosier Energy R E C, Inc	2.7	2016	LFG	IC
IL	PJM	Orchard Hills Renewable Energy Station	Hoosier Energy R E C, Inc	2.7	2016	LFG	IC
IL	PJM	Orchard Hills Renewable Energy Station	Hoosier Energy R E C, Inc	2.7	2016	LFG	IC
IL	PJM	Pilot Hill Wind Farm	EDF Renewable Asset Holdings, Inc.	175	2015	Wind	WT
IN	PJM	Cabin Creek Renewable Energy Station	Hoosier Energy R E C, Inc	2	2016	LFG	IC
IN	PJM	Cabin Creek Renewable Energy Station	Hoosier Energy R E C, Inc	2	2016	LFG	IC
IN	PJM	Fowler Ridge IV Wind Farm LLC	Pattern Operators LP	150	2015	Wind	WT
IN	PJM	Purdue Energy Park	Performance Services	20	2015	Wind	WT
MD	PJM	CNE at Cambridge MD	Constellation Solar Maryland II LLC	3.2	2015	Solar	PV
MD	PJM	Perryman	Constellation Power Source Gen	141	2015	Natural Gas	GT
MD	PJM	Rockfish Solar LLC	Rockfish Solar LLC	10.3	2015	Solar	PV
NC	PJM	Conetoe II Solar, LLC	Conetoe II Solar, LLC	80	2015	Solar	PV
NC	PJM	Creswell Alligood Solar, LLC	Creswell Alligood Solar, LLC	14	2015	Solar	PV
NC	PJM	Downs Farm Solar	Downs Farm Solar, LLC	5	2015	Solar	PV

State	ISO	Plant	Utility	Nameplate Capacity (MW)	First Year of Operation	Fuel Type	Unit Type
NC	PJM	Everetts Wildcat Solar, LLC	Everetts Wildcat Solar, LLC	5	2015	Solar	PV
NC	PJM	GKS Solar	SolNCPower2, LLC	5	2015	Solar	PV
NC	PJM	SolNCPower5, LLC	SolNCPower5, LLC	5	2015	Solar	PV
NC	PJM	Two Mile Solar	SolNCPower1, LLC	5	2015	Solar	PV
NC	PJM	Windsor Cooper HIill Solar, LLC	Windsor Cooper Hill Solar, LLC	5	2015	Solar	PV
NJ	PJM	Clayville	City of Vineland - (NJ)	73	2015	Natural Gas	GT
NJ	PJM	Hanover	NJR Clean Energy Ventures Corporation	5	2015	Solar	PV
NJ	PJM	Harmony	NJR Clean Energy Ventures Corporation	3	2015	Solar	PV
NJ	PJM	Kinsley Landfill Solar	Public Service Elec & Gas Co	8.6	2015	Solar	PV
NJ	PJM	Newark Energy Center	Newark Energy Center, LLC	225	2015	Natural Gas	CT
NJ	PJM	Newark Energy Center	Newark Energy Center, LLC	225	2015	Natural Gas	CT
NJ	PJM	Newark Energy Center	Newark Energy Center, LLC	285	2015	Natural Gas	CA
NJ	PJM	North Run	NJR Clean Energy Ventures Corporation	5	2015	Solar	PV
NJ	PJM	Parkland Landfill Solar	Public Service Elec & Gas Co	7.8	2015	Solar	PV
NJ	PJM	Woodbridge Energy Center	CPV Shore LLC	205	2016	Natural Gas	CT
NJ	PJM	Woodbridge Energy Center	CPV Shore LLC	205	2016	Natural Gas	CT
NJ	PJM	Woodbridge Energy Center	CPV Shore LLC	315	2016	Natural Gas	CA
OH	PJM	GM Lordstown Assembly Solar Array	Solscient Energy, LLC	1.5	2015	Solar	PV
OH	PJM	Oregon Clean Energy Center	Oregon Clean Energy Center	328	2017	Natural Gas	CT
OH	PJM	Oregon Clean Energy Center	Oregon Clean Energy Center	328	2017	Natural Gas	CT
OH	PJM	Oregon Clean Energy Center	Oregon Clean Energy Center	404	2017	Natural Gas	CA
OH	PJM	Walter C Beckjord	Duke Energy Ohio Inc	2	2015	Storage	BA
OH	PJM	Walter C Beckjord	Duke Energy Ohio Inc	2	2016	Storage	BA
PA	PJM	Crawford Renewable Energy - Meadville Po	Crawford Renewable Energy, LLC	99.5	2017	Tires	ST
PA	PJM	Panda Liberty Generation Plant	Panda Liberty O&M LLC	435	2015	Natural Gas	CC
PA	PJM	Panda Liberty Generation Plant	Panda Liberty O&M LLC	435	2016	Natural Gas	CC

State	ISO	Plant	Utility	Nameplate Capacity (MW)	First Year of Operation	Fuel Type	Unit Type
PA	PJM	Panda Patriot Generation Plant	Panda Patriot O&M LLC	435	2016	Natural Gas	CC
PA	PJM	Panda Patriot Generation Plant	Panda Patriot O&M LLC	435	2016	Natural Gas	CC
PA	PJM	Hummel Station (Sunbury Repower)	Panda Power Funds LP	1,124	2017	Natural Gas	CC
PA	PJM	York 2 Energy Center	Calpine Corp	874	2017	Natural Gas	CC
PA	PJM	Caithness Moxie Freedom Station	Caithness Energy LLC	1,050	2018	Natural Gas	CC
PA	PJM	Roundtop	Roundtop Energy LLC	4.4	2015	Natural Gas	IC
PA	PJM	Roundtop	Roundtop Energy LLC	4.4	2015	Natural Gas	IC
PA	PJM	Roundtop	Roundtop Energy LLC	4.4	2015	Natural Gas	IC
PA	PJM	Roundtop	Roundtop Energy LLC	4.4	2015	Natural Gas	IC
PA	PJM	Roundtop	Roundtop Energy LLC	4.4	2015	Natural Gas	IC
VA	PJM	Elkton	Merck & Co Inc	1	2015	Natural Gas	IC
VA	PJM	Elkton	Merck & Co Inc	0.2	2015	Natural Gas	IC
VA	PJM	Flannagan Hydroelectric Project	Jordan Hydroelectric LTD PTP	0.9	2017	Hydro	HY
VA	PJM	Flannagan Hydroelectric Project	Jordan Hydroelectric LTD PTP	0.9	2017	Hydro	HY
VA	PJM	HP Hood CT	HP Hood LLC	15	2015	Natural Gas	GT
WV	PJM	Willow Island Hydroelectric Plant	American Mun Power-Ohio, Inc	22	2015	Hydro	HY
WV	PJM	Willow Island Hydroelectric Plant	American Mun Power-Ohio, Inc	22	2015	Hydro	HY

Unit retirements and environmental retrofits

Table 15 on the following pages lists all announced unit retirements for the state of Pennsylvania. Assumptions for neighboring states are included in an attached spreadsheet, due to the number of units in PJM. Retirement data is based on the 2014 edition of EIA's Form 860, supplemented by ongoing Synapse research. Units without announced retirement dates are assumed to install all required emissions controls, and retire at the end of their lifetime. The cost of control technologies that will be installed at coal plants under existing federal environmental regulations other than the Clean Power

Plan were estimated using the Synapse CAVT tool. These expected retrofits are limited to the years in which specific units have not yet been retired.[266]

Table 15. Pennsylvania's anticipated unit retirements

State	Plant Name	Nameplate Capacity (MW)	Fuel Type	2014 Capacity Factor	Retirement Year	Mothballing Year	Repowering to Gas Year
PA	Cheswick Power Plant 1	637	Coal	52%			
PA	Colver Power Project COLV	118	Coal	82%			
PA	Conemaugh 1	936	Coal	61%			
PA	Conemaugh 2	936	Coal	73%			
PA	Elrama Power Plant 1	100	Coal	0%	2014		
PA	Elrama Power Plant 2	100	Coal	0%	2014		
PA	Elrama Power Plant 3	125	Coal	0%	2014		
PA	Elrama Power Plant 4	185	Coal	0%	2014		
PA	FirstEnergy Bruce Mansfield 1	913.7	Coal	72%			
PA	FirstEnergy Bruce Mansfield 2	913.7	Coal	77%			
PA	FirstEnergy Bruce Mansfield 3	913.7	Coal	66%			
PA	Homer City Generating Station 1	660	Coal	69%			
PA	Homer City Generating Station 2	660	Coal	60%			
PA	Homer City Generating Station 3	692	Coal	67%			
PA	Keystone 1	936	Coal	63%			
PA	Keystone 2	936	Coal	78%			
PA	New Castle Plant 3	98	Coal	10%	2015		

266 For more information, see also: Knight, P. and J. Daniel, Forecasting Coal Unit Competitiveness; CAVT is available at www.synapse-energy.com/tools/coal-asset-valuation-tool-cavt.

State	Plant Name	Nameplate Capacity (MW)	Fuel Type	2014 Capacity Factor	Retirement Year	Mothballing Year	Repowering to Gas Year
PA	New Castle Plant 4	114	Coal	5%	2015		
PA	New Castle Plant 5	136	Coal	14%	2015		
PA	New Castle Plant EMDA	3.2	Oil	0%	2015		
PA	New Castle Plant EMDB	3.2	Oil	0%	2015		
PA	Panther Creek Energy Facility GEN1	94	Coal	72%			
PA	Piney Creek Project GEN1	36.2	Coal	0%			
PA	Portland (PA) 1	172	Coal	16%	2014		
PA	Portland (PA) 2	255	Coal	0%	2014		
PA	Portland 1	172	Coal	0%	2014		
PA	Portland 2	255	Coal	0%	2014		
PA	PPL Brunner Island 1	363.3	Coal	0%			
PA	PPL Brunner Island 2	405	Coal	0%			
PA	PPL Brunner Island 3	847.8	Coal	0%			
PA	PPL Montour 1	864.9	Coal	40%			
PA	PPL Montour 11	17.2	Coal	0%			
PA	PPL Montour 2	893	Coal	50%			
PA	Scrubgrass Generating Company LP GEN1	94.7	Coal	61%			
PA	Seward (PA) FB1	585	Coal	53%			
PA	Shawville 1	125	Coal	37%	2015		
PA	Shawville 2	125	Coal	47%	2015		
PA	Shawville 3	188	Coal	41%	2015		
PA	Shawville 4	188	Coal	45%	2015		
PA	Sunbury Generation LP 1	89.1	Coal	3%	2015		
PA	Sunbury Generation LP 2	89.1	Coal	9%	2015		

State	Plant Name	Nameplate Capacity (MW)	Fuel Type	2014 Capacity Factor	Retirement Year	Mothballing Year	Repowering to Gas Year
PA	Sunbury Generation LP 3	103.5	Coal	0%	2015		
PA	Sunbury Generation LP 4	156.2	Coal	0%	2015		
PA	Westwood Generation LLC GEN1	36	Coal	68%			

Key assumptions

Critical assumptions for both the Reference and PA-100%RE cases are summarized in the table below.

Table 16. Key modeling assumptions

Key Assumption	2020	2030	2040	2050
Reference (business-as-usual) Case: Based on current statutes; most likely future in the absence of new policies				
Electric energy efficiency (excludes new electrified uses): share of PA retail electric sales in cumulative savings from 2012 based on 1% annual incremental savings; includes measure retirement at end of lifetime	6.8%	9.1%	9.2%	9.3%
Renewable Portfolio Standard: WWS renewables only (6% in 2020); adjusted for share of state sales required to comply (97%(	5.8%	5.8%	5.8%	5.8%
Nuclear generation unit retirements	One license extension (60 year life)			
Fossil-fuel generation unit retirements	Announced retirements (see separate spreadsheet) + economic			
Coal generation unit retrofits	Required retrofits (see separate spreadsheet)			
Electric generating capacity additions	Current underconstruction additions (through 2017) + economic			
Clean Power Plan compliance	Mass-based (existing + new) compliance path, no delay from stay, wide-spread trading			
Non-electric sector changes over time	Based on U.S. EIA Annual Energy Outlook 2015 projections for PA region			
PA-100%RE Case: Electric-sector assumptions				
Electric energy efficiency (excludes new electrified uses): share of PA retail electric sales in cumulative savings from 2012 based on 3% annual incremental savings; includes measure retirement at end of lifetime	7.8%	20.8%	23.4%	23.5%
Thermal energy efficiency	Embedded in electric values; no additional gas efficiency			
Renewable Portfolio Standard: WWS renewables only (10% in 2020); adjusted for share of state sales required to comply (97%)	9.7%	39.8%	69.9%	100%
Minimum share of RECs purchased from PA to comply with PA RPS	Not specified as an input to modeling			20%
Wind sited in PA: minimum MW	1,700 MW	5,000 MW	7,000 MW	8500 MW
DG PV sited in PA: minimum MW	650 MW	8,000 MW	16,000 MW	25,000 MW
Utility PV sited in PA: minimum MW	300 MW	4,000 MW	10,000 MW	25,000 MW
Nuclear generation unit retirements	One license extension (60 year life)			
Fossil-fuel generation unit retirements	Announced retirements (see separate spreadsheet) + economic			
Coal generation unit retrofits	Required retrofits (see separate spreadsheet)			
Electric generating capacity additions	Current underconstruction additions (through 2017); then no new fossil-fuel infrastructure sited in PA			
Carbon policy assumptions (including Clean Power Plan)	No incremental carbon policy (decarbonization driven by RPS)			
PA-100%RE Case: Electrification assumptions				
Transition of motor gasoline powered vehicles	4%	33%	75%	100%
Transition of non-gasoline powered vehicles (electric vehicles)	2%	15%	50%	100%
Transition of planes (hydrogen fuel cell vehicles)	0%	0%	50%	100%
Transition of heating to heat pumps (residential and commercial)	25%	40%	75%	100%
Transition of water heating (residential and commerical)	35%	45%	80%	100%
Other electrification (residential and commercial)	2%	15%	50%	100%
Industrial amenable to electrification	20%	36%	61%	100%
Industrial recalcitrant to electrification: no electrification; offsets purchased	0%	0%	0%	0%
Scope of Analysis				
Years modeled	Even years from 2018 to 2050; only 2020, 2030, 2040, and 2050 reported			
Energy-related CO_2 emissions	Included in analysis			
Non-CO_2 greenhouse gas emissions	Not included in analysis			
Upstream emissions	Not included in analysis			
Non-energy emissions (LUCF, agriculture)	Not included in analysis			
REC and emissions inventory accounting assumptions for PA	Energy-related emissions only; geographic (within state lines) inventory attributing emissions in this order: (1) non-electric emissions (and offsets if necessary); (2) in-state REC purchases; (3) out-of-state REC purchases; (4) in-state non-REC generation up to level of sales; (5) PJM non-REC generation up to level of sales if needed			

APPENDIX B: JOB MODELING METHODOLOGY

Synapse used the National Renewable Energy Laboratory's (NREL's) Jobs and Economic Development Impact (JEDI) models to estimate the net employment impacts within Pennsylvania of achieving an entirely renewable energy system.[267] The JEDI models are resource-specific input-output tools that estimate employment impacts based on cost inputs for the construction and operations and management (O&M) phases of an electric generation or transmission resource. Synapse used electric system cost outputs for the two scenarios from the NREL's Regional Energy Deployment System (ReEDS) to calculate the difference in resource-specific construction and O&M costs between the Policy and Reference cases over the 2016-2050 study period. These incremental costs were then input into JEDI models, using JEDI default assumptions regarding the breakdown of total construction and O&M costs by expenditure type. The JEDI models then produced employment impact results, which Synapse converted into units of job-years for purposes of consistency.

These jobs results are a first pass accounting for likely employment impacts and include only the employment impacts of changes in electricity generation and transmission. They do not reflect the impacts of investments in energy efficiency or end-use electrification technologies, and therefore may underestimate the employment benefits of a transition to an all-renewable energy system. The accuracy of these job estimates depend upon generalized JEDI default assumptions regarding the percentage of various goods and services that are purchased within Pennsylvania. The analysis does not account for job changes by industry or the changing ratio of short-term jobs (e.g. construction) and long-term jobs (e.g. operations and maintenance).

Further analysis would be necessary to achieve greater detail and certainty in estimating the jobs associated with the PA-100%RE case; for example, more thorough analysis of state economy and jobs impacts could be performed using IMPLAN or another proprietary input-output model.[268] Like the simplistic JEDI-based analysis presented here, however, a more detailed input-output analysis would not account for a transition from many employees located on fewer jobsites (changes to employment that are often well-covered by media) to many more job sites with fewer employees on each site.

[267] JEDI is a publicly available model developed by NREL. Information on JEDI is available at www.nrel.gov/analysis/jedi/.

[268] IMPLAN is a commercial model developed by IMPLAN Group PLC. Information on IMPLAN is available at: www.implan.com/.