Pennsylvania Climate Action Plan 2021

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pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Pennsylvania Climate Action Plan 2021

Updated Draft

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Acknowledgements and Disclaimer

This material is based upon work supported by the United States Department of Energy, Office of Energy Efficiency and Renewable Energy, under State Energy Program Award Number DE-EE0008293.

This update is a report that was prepared in response to the Pennsylvania Climate Change Act (Act 70 of 2008), which requires the DEP to prepare a climate action plan regularly. The Pennsylvania Climate Change Advisory Committee provided input and feedback to the DEP and ICF for the preparation of this assessment. The Climate Change Advisory Committee has 18 members plus 3 ex officio members. The 2021 Climate Action Plan is the fifth iteration of the Pennsylvania Climate Action Plan and builds on the previous action plans. This report and the analyses contained within it were prepared by the Pennsylvania DEP with support from ICF, Penn State University and Hamel Environmental Consulting.

This draft plan is a working document, intended to be a tool to share continual updates on analysis and information with the CCAC. All content is subject to change and additional refinement, and may still be under development.

For More Information

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https://www.dep.pa.gov/Citizens/climate/Pages/default.aspx

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EXECUTIVE SUMMARY

- ~5 pages long (could be longer if intended to be the “pullout” or the booklet used for public and stakeholders. Likely no more than 10 pages.
- High-level overview of each primary section in the main report
- Present key results and takeaways
- Use key graphics from report
- Design to be a standalone version of the broader plan

1 INTRODUCTION

Act 70 and EO 2019-01

The Pennsylvania Climate Change Act of 2008 (Act 70) requires the Department of Environmental Protection (DEP) to compile an annual greenhouse gas (GHG) inventory for Pennsylvania's emissions, to develop a voluntary GHG registry, and to conduct a climate action plan (CAP) and impacts assessment (IA) and update them every three years. Act 70 also establishes a Climate Change Advisory Committee (CCAC) to advise DEP during the development of the impacts assessment and climate action plan. Working with the CCAC, DEP has prepared a series of climate action plans and GHG mitigation strategies since Act 70's creation in 2008.

Act 70 Requirements:

- Compile annual GHG inventory
- Develop a voluntary registry of GHG emissions
- Conduct a Climate Action Plan and Impact Assessment
- Establish a Climate Change Advisory Committee

Executive Order 2019-01:

- Recognizes the risks of climate change for Pennsylvanians
- Set GHG reduction targets of 26% by 2025 and 80% by 2050 (from 2005 levels)
- Reestablished the GreenGov Council

In 2019, just prior to the release of the fourth iteration of the Pennsylvania Climate Action Plan, Governor Tom Wolf issued Executive Order 2019-01 (EO 2019-01, Commonwealth Leadership in Addressing Climate Change and Promoting Energy Conservation and Sustainable Governance). This EO establishes a climate goal for Pennsylvania and includes a "Lead by Example" provision for the state government that re-established the GreenGov Council to encourage the state to incorporate environmentally sustainable practices into the Commonwealth's policy and planning decisions. Additionally, the EO recognizes that "climate change impacts in Pennsylvania are real and continue to put Pennsylvanians at risk: in recent years, extreme weather and natural disasters have become more frequent and more intense. Like many areas of the United States, Pennsylvania is expected to experience higher temperatures, changes in precipitation, and more frequent extreme weather events and flooding because of climate change in the coming decade."

EO 2019-01 specifically states that the "Commonwealth shall strive to achieve a 26 percent reduction of net greenhouse gas emissions statewide by 2025 from 2005 levels, and an 80 percent reduction of net greenhouse gas emissions by 2050 from 2005 levels." These goals are in line with the goals of the Paris Agreement.[1] This updated 2021 Climate Action Plan includes a prioritized set of GHG reduction strategies that, if implemented successfully, could reduce future GHG emissions to levels that actualize the EO GHG reductions goals. This 2021 Plan also recognizes and maps out flexible strategies and pathways for adapting to the impacts of climate change in Pennsylvania, buildings directly from the 2021 Climate Impact Assessment.

[1] The stated goal of the Paris Agreement is "to limit global warming to well below 2 degrees Celsius, preferably to 1.5 degrees Celsius, compared to pre-industrial levels." Details on the Paris Agreement can be found on the UNFCCC website, available here: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement#:~:text=The%20Paris%20Agreement's%20central%20aim,further%20to%201.5%20degrees%20Celsius.

Pennsylvania's Evolving Energy and Climate Efforts

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Since the initial CAP and IA were developed and published in 2009, Pennsylvania's approach to addressing climate change has evolved as science and technology continue to mature and the Commonwealth's context and needs change. While some key energy policies that have climate benefits, such as the Alternative Energy Portfolio Standard (AEPS) and Act 129 were in place when the first CAP was published (see Figure 1), the CAP process is an important method that allows DEP to map out how hallmark policies and programs can continue to evolve, and to determine how new policies and programs can lead to further GHG reductions, increased resiliency, and reduced risk from climate impacts to the benefit of all Pennsylvanians. In some cases, past CAPs have helped lay the foundation for new programs that are being developed now, most notably Pennsylvania participating in the Regional Greenhouse Gas Initiative (RGGI), developing the Pennsylvania Commercial Property Assessed Clean Energy (C-PACE) Program,[2] and ongoing industrial energy assessments.[3]

This 2021 Pennsylvania Climate Action Plan is the fifth iteration of the CAP. It builds on previous plans and includes the latest science on the impacts of climate change, the near- and long-term emission reduction goals for the Commonwealth from EO 2019-01, new and expanded strategies to reduce GHG emissions and prepare for the impacts of climate changes, and the consideration of how the strategies outlined in this plan effect public health and equity.

Figure 1. Pennsylvania's Evolving Energy and Climate Planning and Implementation Efforts

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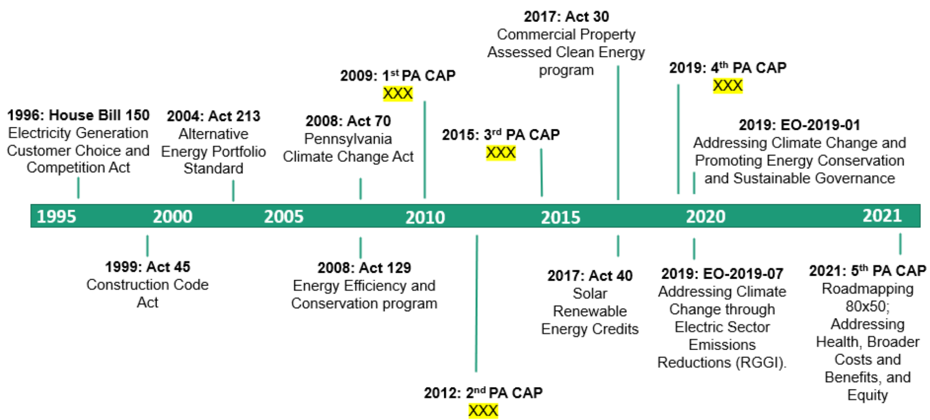


[2] See: https://www.dep.pa.gov/Business/Energy/OfficeofPollutionPrevention/FinancialOptions/Pages/C-PACE.aspx.

[3] See: https://www.dep.pa.gov/Business/Energy/OfficeofPollutionPrevention/State-Energy-Plan/Pages/Energy-Assessments.aspx.

The Impacts of Climate Change in Pennsylvania

Climate change is already affecting Pennsylvania. From severe heat waves to significant flooding, climate change influences weather events that have economic, health, and other impacts across the Commonwealth. These events can affect some Pennsylvanians more than others.

By mid-century, key expected climatic changes compared to a 1971-2000 baseline include:

- The average annual temperature statewide is rising, and is expected to increase by 5.9°F (3.3°C).
- There will be more frequent and intense extreme heat events. For example, temperatures are expected to reach at least 90°F on 37 days per year, up from the 5 days during the baseline period (see Figure 2). Days reaching temperatures above 95°F and 100°F will become more frequent as well.
- Increasing temperatures will continue to alter the growing season and increase the number of days that people need to cool their homes and workspaces, but will also decrease the number of days that people will need to use heating.
- Pennsylvania could experience more total average rainfall, occurring in less frequent but heavier rain events. Extreme rainfall events are projected to increase in magnitude, frequency, and intensity (see Figure 3) and drought conditions are also expected to occur more frequently.
- Tidally influenced flooding is expected to increase in the Delaware Estuary coastal zone.
- Lake Erie is also expected to undergo significant changes in water level, coastal erosion, and water temperature.

These and other existing and future climate changes are described in further detail in section 4.

As Pennsylvania works to reduce its climate risks, it must address these inequitable impacts and ensure that adaptation efforts do not inadvertently exacerbate inequities. Instead, adaptation actions should reduce impacts on vulnerable populations. This assessment identified the following top priorities for adaptation action:

- Reduce extreme heat risks to human health, particularly for vulnerable populations.
- Support the agriculture, recreation, and tourism sectors, as well as forests, ecosystems, and wildlife in the transition to a warmer climate.
- Reduce flood risks to infrastructure and communities.
- Help low-income households cope with an increased energy burden.
- Enhance tropical storm and landslide risk mitigation.

Climate risks and related impacts in Pennsylvania could be severe, potentially causing increased infrastructure disruptions, higher risks to public health, economic impacts, and other changes, unless actions are taken by the Commonwealth to avoid and reduce the consequences of climate change.

Increasing average temperatures and heavy precipitation and inland flooding emerged as the two highest-risk hazards by mid-century. Both hazards could affect the entire state and all sectors Figure 3). Increasing temperatures have the highest consequences for human health and environmental justice and equity, especially in urban areas. Heavy precipitation and flooding could also have severe consequences for human health, agriculture, and built infrastructure, with populations, farms, and infrastructure located in or near floodplains at particular risk.

Figure 2. Observed and projected annual days with temperatures above 90°F

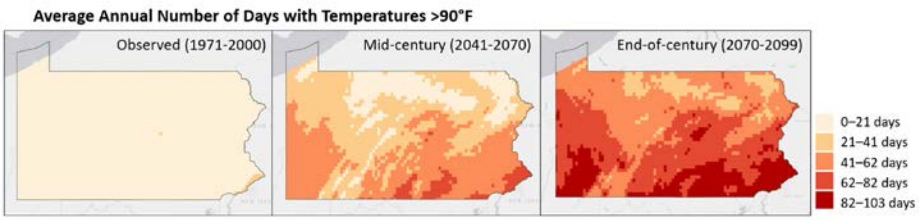
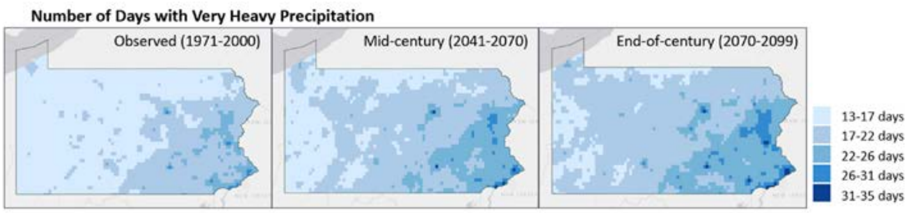


Figure 3. Observed and projected annual days with "very heavy" precipitation



Pennsylvania's Current Energy Profile and Hallmark Policies

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The Commonwealth of Pennsylvania is a leading energy producer and supplier, which serves as a driver for a lot of the economy, poses challenges and opportunities for reducing GHG emissions and improve energy infrastructure resilience to slow and mitigate the impacts of climate change. Pennsylvania's energy profile has become increasingly dynamic in recent decades, as both fossil fuel and clean energy generation have grown. The Commonwealth is one of the nation's leading natural gas producers, second only to Texas and the largest electricity generator in PJM, making it a net exporter of energy. Falling costs for renewable energy and policies such as the Alternative Energy Portfolio Standard (AEPS), and recent requirements such as for in-state solar generation to meet AEPS thresholds have boosted the role of renewables in the energy mix. Zero emissions generation in Pennsylvania is heavily reliant on nuclear power. Additionally, at the direction of Governor Wolf, DEP is currently undertaking a rulemaking process to enable Pennsylvania to join the Regional Greenhouse Gas Initiative (RGGI). Participation in RGGI could lead to a significant increase in

How anticipated federal changes may influence Pennsylvania's energy and climate efforts

List out a few key anticipated changes and how they may affect this plan and Pennsylvania's environmental and economic context. Will list as late as possible, likely April with more information available clean energy programs, beginning in 2022.[4] Oil and coal production and use, while reduced over the past decade, are still present in Pennsylvania.

Energy efficiency has also become a significant energy resource, through state policies such as Act 129 of 2008, requiring the seven largest electric distribution companies to develop energy efficiency and conservation plans and other methods of reducing residential and commercial customers' electricity consumption. Currently one in six households in Pennsylvania use fuel oil as a heating source though' the majority of these households being in rural areas. With a large industrial footprint (e.g., natural gas and oil extraction and mining; metals and machinery manufacturing; chemical products; and agriculture and food processing), electricity and fuel consumption continues to grow for the industrial sector. Because of the expansive state geography, large rural areas, and urban areas at opposite sides of the state, fuel use for consumers in Pennsylvania is relatively high, but because of the state renewable fuels mandate, production and use of ethanol and biofuels is prevalent. To potentially further a clean energy transition in the transportation sector, DEP is also actively engaged in involved in the development, outreach, and engagement of the Transportation and Climate Initiative.

The Effects of COVID-19

- Economic Impacts
  - E2 Report Clean Energy Unemployment from COVID-19
    - By December 2020, clean energy jobs had declined by 12% from the year prior
    - Only 30% of jobs lost in the early months have been recovered and projections estimate it will take years for the sector to fully recover
    - Women and people of color have been disproportionally affected by job losses.
    - As of December 2020, Pennsylvania had lost 17,044 clean energy jobs, about 17.2% of all clean energy jobs.
  - Clean Jobs Pennsylvania 2020
    - 18,000 clean energy workers remain jobless as of August 2020.
    - 85% of clean energy workers left unemployed by the pandemic have not returned to work.
  - Reimagine Appalachia Report
    - From March 21,2020 to January 2, 2021, 2.57 million Pennsylvanians filed unemployment insurance claims (39.2% of the pre-pandemic labor force).
    - For the 2020 fiscal year that ended in June 2020, the state's tax revenue fell short by around $3.2 billion. This represented a budget gap of about 9% relative to the $34 billion 2020 fiscal year budget. The state's official forecast as of May 2020 was for a budget shortfall of up to $5 billion in its general fund on a combined basis for fiscal years 2020 and 2021. This amounts to about 7.1 percent of combined general fund expenditures for these two fiscal years
    - Estimates that approximately 152,000 permanent clean energy jobs will be generated in 2021, and additional jobs each year thereafter as clean

Commented [HD4]: Note for the CCAC: We are working the flesh out this section more, feedback on content as we continue to write would be useful. We may also updated throughout the writing process as new information comes out

Commented [D5R4]: Note also that the AEO 2021 was JUST published last week, so we will be looking at that to see if there is information we can rely on.

[4] For additional information on Pennsylvania's current energy profile and policies, see DEP's Clean Energy Program Plan, available at: https://www.dep.pa.gov/Business/Energy/OfficeofPollutionPrevention/Pages/default.aspx#:~:text=The%20Clean%20Energy%20Program%20(CEP,and%20mitigate%20disruptions%20to%20ensure.

energy investments increase and economic activity in Pennsylvania recovers.

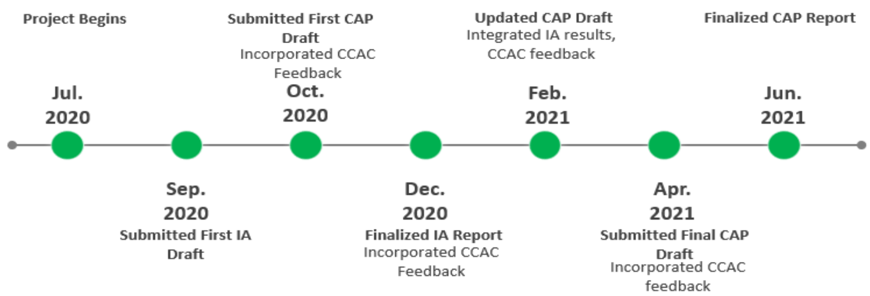
- Healthcare Impacts (HMA Analysis of the Impacts of COVID-19 on Pennsylvania Hospitals)
    - Patient volume plummeted and will remain well below pre-pandemic levels
    - Large margin shortfalls occurred across the state, well in excess of federal relief payments.
    - The ongoing health crisis presents substantial challenges on many fronts including:
        - Flu season and potential second surge.
        - Potential workforce shortages form sick employees.
        - A struggling economy leading to lack of health coverage.
    - Investment in facilities, equipment and technology is being deferred.
    - The long-term viability of some hospitals is threatened.
- DEP, Energy Programs Office Gap Analysis
    - EPO is working with BW Research on workforce development data. BW has recently conducted a survey of employers and training providers to identify training needs and gaps for the clean energy sector. A report on the outcomes of the surveys and identification of workforce gaps is expected to be released in Spring 2021.
- GHG modeling does not account for the effects of COVID-19.
    - Without even a year of data available, analyses and short-and long-term effects of COVID-19 on behaviors and trends are highly uncertain.
    - Incorporating COVID can be an improvement made in the 2024 CAP when the data are more certain and robust. Impacts of efforts like this take years to materialize in available data.

The CAP Development Process

The development of this CAP was informed by the current and anticipated climate risks Pennsylvania faces, and builds upon the historical and current climate efforts undertaken by DEP and others. DEP led the development of the Impact Assessment (IA) and this CAP—two interrelated work streams that were developed concurrently. The ICF team, including its partners at Pennsylvania State (Penn State) University and Hamel Environmental Consulting, was responsible for modeling the BAU, GHG reduction strategies, and adaptation strategies, provided technical expertise throughout the process, and contributed to the writing of this report. Additionally, DEP Energy Programs Office engaged other DEP Offices and state agencies throughout this planning process, including the DEP Office of Environmental Justice 4 and Bureau of Air Quality and the Department of Natural Resources. DEP also engaged in public outreach through surveys, open to all Pennsylvanians, to gather information and feedback to feed this plan. Finally, throughout the process, DEP shared updates with and sought feedback from CCAC, as mandated in Act 70, to improve the final CAP. This inclusive and iterative process ensured that diverse opinions and information sources were integrated into an informed and comprehensive final IA and CAP.

Work on this Climate Action Plan began in July 2020 and initially focused on assessing climate impacts through the development of the IA during the second half of 2020. Several drafts of the IA were shared with CCAC and other stakeholders over this time to improve and refine the analysis and final report. The IA uses a risk-based approach to assess the impacts of climate change, which directly feeds into the adaptation strategies identified in this CAP. At the same time, the project team was selecting and prioritizing GHG strategies and engaging with other DEP offices and the CCAC to gather initial input on the strategies and a vision for this plan. Engagement with stakeholders continued as efforts to conduct modeling and develop plan content were ongoing. Similar to the IA, multiple drafts of the CAP were shared with the CCAC. This final CAP report is the culmination of this year-long effort. Figure 4 provides an overview of the IA and CAP development process timeline.

Figure 4. CAP Process Timeline



Report Contents

The purpose of this report is to clearly describe DEP's plan to reduce Pennsylvania's contribution to climate change and adapt to the current and future impacts of climate change. Below is a brief outline of the contents.

- **Pennsylvania's Greenhouse Gas Inventory, Forecast, and Current GHG Reduction Efforts** – describes Pennsylvania's current GHG emissions profile, the results of the business-as-usual projection, and the ongoing climate efforts.
- **Opportunities for Reducing GHG Emissions in Pennsylvania** – outlines the approach used to identify and select GHG reduction strategies and provides a detailed description of each selected strategy and select enabling technologies.
- **The Impacts of Climate Change in Pennsylvania and Ongoing Adaptation Efforts** – summarizes the priority climate risks and impacts, as well as ongoing adaptation efforts.
- **Opportunities to Adapt to the Impacts of Climate Change in Pennsylvania** – defines the approach taken to identify and select adaptation strategies and pathways and describes the selected pathways.
- **Implementing Climate Action in Pennsylvania** – details challenges and implementation to implementing climate action, implementation principles, and key steps and stakeholders for effective implementation of the CAP.

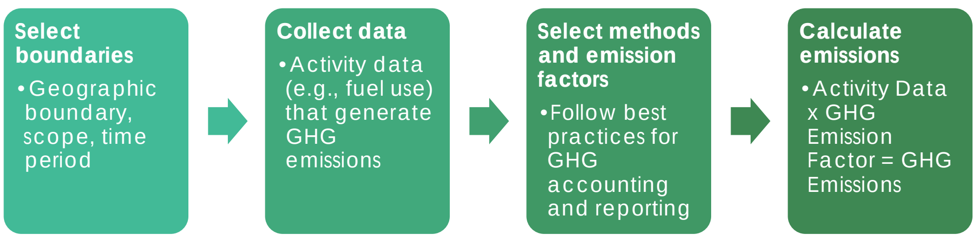
2 PENNSYLVANIA'S GREENHOUSE GAS INVENTORY, FORECAST, AND CURRENT GHG REDUCTION EFFORTS

Pennsylvania's latest greenhouse gas (GHG) inventory provides a snapshot of GHG emissions in the Commonwealth from 2000 to 2017. This inventory is used to track progress towards reducing GHGs over time, and forms the basis of the business as usual (BAU) emissions scenario. The BAU scenario projects what emissions in Pennsylvania would be through 2050 if only the existing (as of December 2020) GHG reduction policies and programs continue.

Current GHG Emissions

The GHG inventory process, summarized below in Figure 5, is used to create a consistent inventory that can be compared over time as each new inventory is developed. In 2020, DEP developed Pennsylvania's most recent GHG inventory for 2017 emissions by using the EPA's State Inventory Tool (SIT), an Excel-based tool that follows a standardized process to generate state-level emission estimates. The SIT was used to develop GHG emission estimates for intervals from 2000 through 2017, the last year for which data was available as of the publication of this report.

Figure 5. The Inventory Development Process



Emissions from the following sectors are included in the inventory:

- Residential Fuel Use
- Commercial Fuel Use
- Industrial Fuel Use and Process Emissions
- Fugitive Emissions from Energy Production
- Transportation
- Electricity Generation
- Agriculture
- Waste Management
- Forestry and Land Use (natural carbon sinks)

Figure 6 shows a breakdown of 2017 GHG emissions in Pennsylvania by sector. Figure 7 provides a summary of historical GHG emissions in Pennsyvlania by sector. Note that these figures and in-text numbers use Million Metric Tons of Carbon Dioxide equivalent ($MTCO_2e$) units to aggregate all GHG emissions (see text box "Carbon dioxide equivalence and global warming potential explained" for further details). The Pennsylvania GHG Inventory and the Inventory of U.S. Greenhouse Gas Emissions and Sinks annual report each provide more granular emissions data disaggregated by each GHG for the interested reader.

Figure 6. Pennsylvania 2017 GHG Emissions by Sector

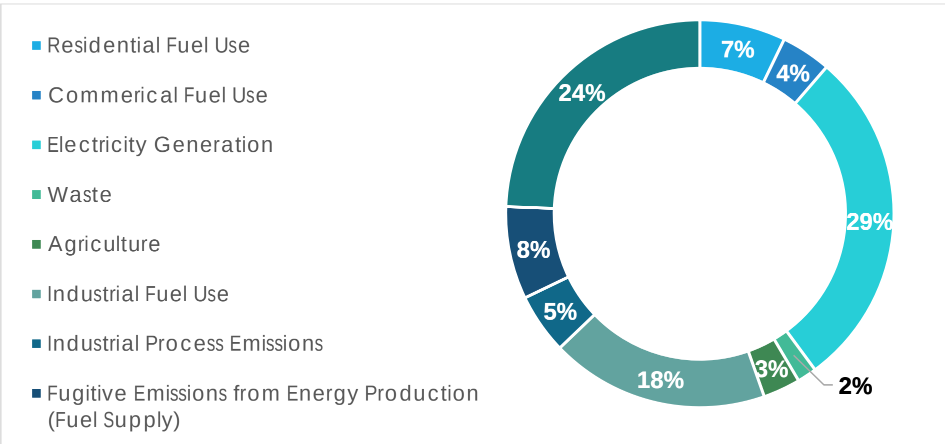
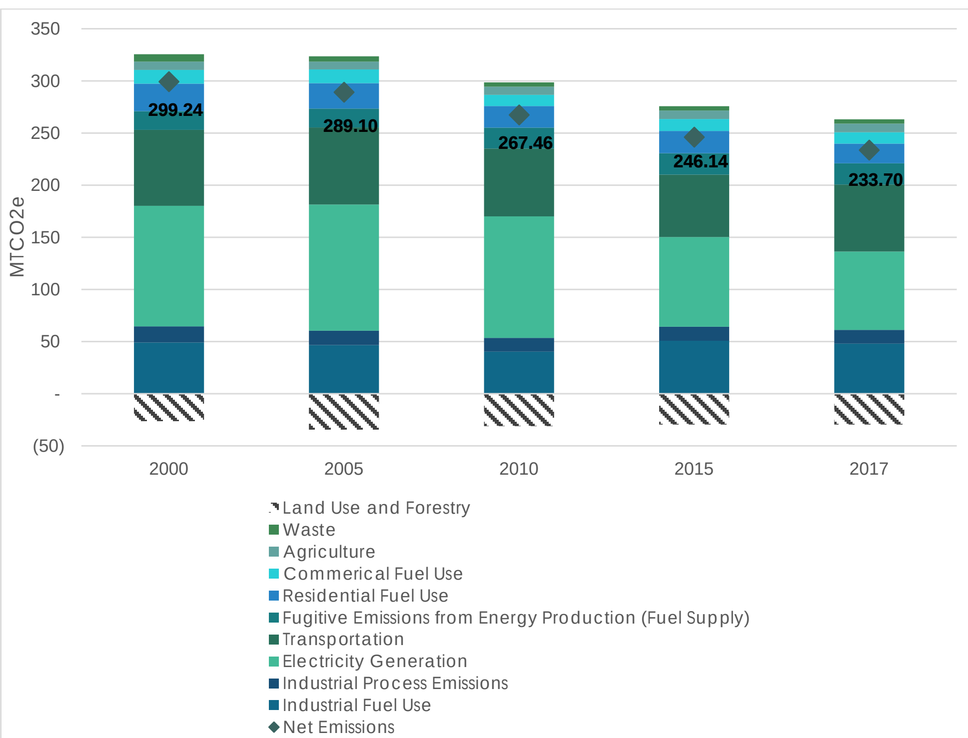


Figure 7. Pennsylvania Historical Net GHG Emissions by Sector ($MTCO_2e$)*



Total statewide gross GHG emissions in 2017 were 263.2 $MTCO_2e$. Pennsylvania's Land Use, Land-Use Change and Forestry (LULUCF) sector acts as a carbon sink for GHG emissions. In 2017, the LULUCF sector sequestered 29.5 $MTCO_2e$, resulting in statewide net GHG emissions of 233.7 $MTCO_2e$. 2017 net emissions are 19.2% lower than in 2005, when ne emissions were 289.1 $MTCO_2e$. These reductions get Pennsyslvaina about three-quarters of the way towards its 2025 GHG redction goal of reducing GHG emissions 26% from 2005 levels by 2025.

Gross vs. Net Emissions:

"Gross emissions" includes only source categories with positive emissions, while "net emissions" include source categories with both positive and negative emissions. For Pennsylvania, net emissions are equal to gross emissions plus negative emissions from forestry and land use.

Emissions have declined since 2005 in the majority of sectors, with the exception of industrial (enegy and process) and agricultural emissions. As of 2017, the following sectors were the largest sources of emissions, presented in from largest to smallest:

1. Electricity generation
2. TransportationIndustrial emissions
3. Fugitive emissions from energy generation (including coal mines and oil and gas production)
4. Residential and commercial fuel use

Note that this CAP breaks out industrial emissions and fugitive emissions from energy production to be able to better translate to the GHG inventory to emission reduction straregies in Section 3 below. However, for GHG inventory purposes, both of these sources are included in the industrial sector, and when added together make up the largest shared of emissions in the Commonwealth. Electricity generation, transporation, industrial energy and process emissions, and fugitive energy production emissions account for 95% of total GHG emissions in Pennsyslvania. Recent trends in these sectors are briefly discussed below.

- **Electricity Generation:** Emissions from electricity generation decreased 7% from 2016 to 2017, and decreased 38% from 2005 to 2017. This is mainly a result of decreased electricity generation from coal being offset by increases in natural gas generation, energy efficiency improvements as a result of Act 129, and increased electricity generation from alternative and renewable energy sources as a result of the AEPS. Coal-based electricity generation has decreased from generating 56% of Pennsylvania's

Carbon dioxide equivalents and global warming potential explained

Carbon dioxide equivalent (CO_2e) is a measure used to compare the emissions from various GHGs based upon their global warming potential (GWP). GWPs allow for the comparison of the potential global warming impact of different GHGs by measuring the relative atmospheric warming effect of one ton of a GHG relative to the emissions of one ton of CO_2, accounting for differences in time. GWPs for each GHG are assessed in each of the International Panel on Climate Change's (IPCC) comprehensive climate change Assessment Reports. The IPCC has completed five assessment cycles. GWP values for the IPCC's Fourth Assessment Report (AR4) are commonly used in reporting, and the U.S. National GHG Inventory currently these values to develop emission estimates.

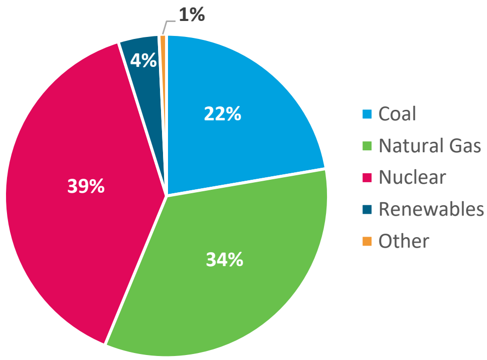
For example, the AR4 GWP for CH_4 is 25, indicating that one metric ton (MT) of CH_4 has a warming potential equivalent to 25 MT of CO_2. It is standard practice to report GHG inventory emissions in $MTCO_2e$. **Table 1** displays GWP values from the Fourth Assessment Report for CO_2, CH_4, and N_2O.

Table 1. Fourth Assessment Report GWPs

GHG	AR4 GWP
CO_2	1
CH_4	25
N_2O	298

electricity in 2005 to 22% in 2017. In 2017, nuclear power is the largest source of electricity generated in Pennsylvania, providing 39% of all electricity. Figure 8 shows a breakdown of electricity generated in Pennsylvania in 2017 by fuel type. These data are from 2017; however, the Commonwealth's electricity generation mix has and will continue to change each year, as outlined in the BAU discussion below (see Figure 10). Notably, as of 2020, natural gas is now the largest electricity geneating source in Pennsylvania.

Figure 8. 2017 Electricity Generation by Fuel Type



- **Transportation:** In 2017, the transportation sector emitted 64.3 $MTCO_2e$. The majority of these emissions were from gasoline-powered personal vehicles. Since 2005, transportation emissions have decreased 11%, mainly due to increased fuel efficiency standards.
- **Industrial:** Industrial emissions make up 23% of Pennsylvania's emissions in 2017, and have increased 1% above 2005 levels to 61.2 $MTCO_2e$. The majority (48.0 $MTCO_2e$) of industrial emissions result from the combustion of fossil fuels,. Other major sources of emissions include cement manufacturing (1.8 MT CO_2e), iron and steel production (3.8 MT CO_2e) and the use of ozone-depleting substance (ODS) substitutes (6.0 MT CO_2e), all of which are estimated by EPA's State Inventory Tool (SIT). The industrial sector estimates from SIT also include emissions from sources such as lime manufacturing, soda ash production, and electric power transmission and distribution systems.
- **Fugitive Emissions from Energy Production.** Fugitive emissions in the industrial sector contributed 20.3 $MTCO_2e$ in 2017, of which 10.7 $MTCO_2e$ was emitted by coal mining, and 9.7 $MTCO_2e$ was emitted by natural gas and oil systems. Natural gas and oil systems includes fugitive emissions from production, transmission, and storage of natural gas and petroleum products. Fugtive energy emissions have increased 13% since 2005 (18 $MTCO_2e$ to 20.6 $MTCO_2e$). Over this time period, emissions from coal mining have decreased and emissions from oil and gas systems have increased to the point where each accounf for about half of the emissions in 2017.
- **Residential and Commercial Fuel Use:** Residential and commercial emissions from fuel use (i.e., not including electricity consumption, but including on-site fuel combustion) are a result of the direct use of fuels in homes, businesses, institutional facilities (e.g., schools), and other large buildings. Emissions from the residential and commercial sectors have decreased 20% since 2005, likely a result of both fuel switching to lower emitting fuels for heating, and energy efficiency improvements as a result of both Act 129 (which requires

efficiency improvements that also impact fuel consumption, in addition to the required reductions in electricity use) and technology improvements over time (e.g., ENERGY STAR certified products).

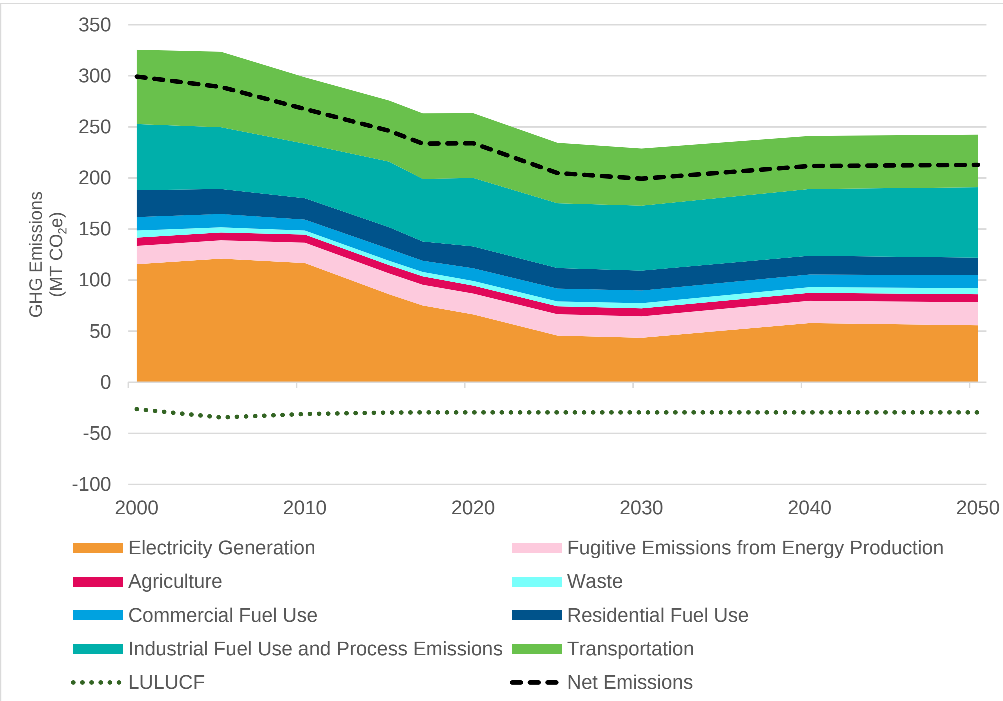
BAU Overview

Pennsylvania's BAU scenario uses the most recent Pennsylvania GHG inventory as a starting point, and projects GHG emissions through 2050 under the current GHG reduction policies and programs being implemented.[5] The BAU serves as a benchmark for Pennsylvania's GHG reduction planning by providing emissions estimates that can be compared against emissions estimates for selected GHG reduction strategies.

Figure 9 below shows BAU emissions estimates by sector, from 2000 through 2050 (years 2000 – 2017 are actual emissions, 2018 – 2050 are projected). Under the BAU scenario, Pennsylvania's net emissions are projected to be 212.82 $MTCO_2e$ in 2050, a 26% decrease from 2005 levels (289.10 $MTCO_2e$), including carbon sinks. Consistent with the GHG accounting approaches used in the GHG inventory, decreases in emissions from the electric power sector are included in the "electricity generation" category, not with the associated end-use. (i.e., the residential, commercial, industrial, and transportation sectors include emissions from the use of fuels on-site).

[5] For a full list of the policies and programs included in the BAU, please refer to Appendix B.

Figure 9: BAU Net Emissions by Sector, 2000-2050 ($MTCO_2e$)



Under the BAU scenario, Pennsylvania will achieve its 2025 reduction goal, but will not meet its 2050 reduction goal of 80% from 2005 levels. 2025 net emissions are projected to be 204.86 $MTCO_2e$, a 29% decrease from 2005 emissions (289.10 $MTCO_2e$), which is beyond the target set in EO 2019-01. Beyond 2025, however, BAU emissions are projected to increase slightly. 2050 net emissions are projected to be 212.82 $MTCO_2e$ with no additional policy changes, a 26% decrease below 2005 levels. Between 2025 and 2050, net emissions are estimated to increase by 4%. The increase in net emissions between 2025 and 2050 is largely due to increased emissions from electricity generation and industrial energy emissions. Table 2 provides a summary of GHG emissions by sector, with percent change from 2005 to 2050.

Table 2: Pennsylvania Emissions by Sector, BAU Scenario (MT CO_2e)

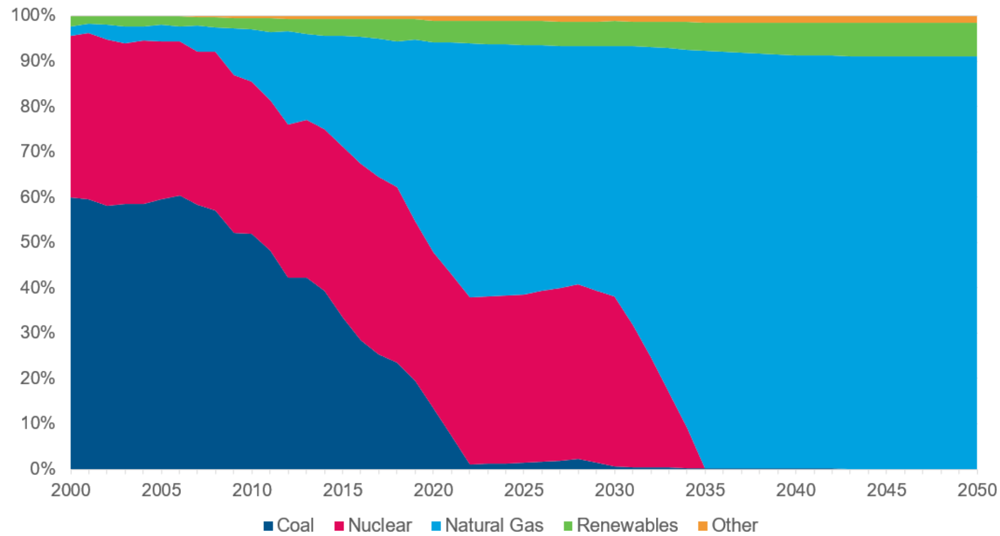
Sector	2005	2017	2025	2030	2050	% Change (2005-2050)
Electricity Generation	121.0	75.2	45.7	43.5	55.7	-53.9%
Residential Fuel Use	24.4	18.9	20.2	19.4	17.3	-29.0%
Commercial Fuel Use	13.1	11.0	12.4	12.4	12.5	-4.6%
Industrial (Process and Energy)	60.5	61.2	63.4	63.6	68.9	14.0%

Transportation	73.9	64.3	59.2	56.0	51.4	-30.5%
Fugitive Emissions from Energy Production	18.1	20.3	21.0	21.0	22.7	25.4%
Agriculture	7.6	8.2	7.7	7.7	7.7	2.3%
Waste	5.1	4.3	4.9	5.2	6.1	19.7%
Gross Emissions	323.6	263.2	234.4	228.8	242.4	-25.1%
LULUCF	(34.5)	(29.5)	(29.5)	(29.5)	(29.5)	-14.4%
Net Emissions	289.1	233.7	204.9	199.3	212.8	-26.4%

Emissions from electricity generation are projected to be 55.7 $MTCO_2e$ in 2050, a 54% decrease from 121.0 $MTCO_2e$ in 2005. The projected decrease in emissions by 2050 from 2005 levels is driven primarily by the decrease in emissions from electricity generation, which decreases sharply by 64% between 2005 and 2030 as a result of switching from coal to gas generation due to economic and market factors (see Figure 10). Additional changes in generation from higher emitting to lower emitting sources before 2030 are driven partly by AEPS and RGGI. The BAU modeling assumes that the AEPS and RGGI requirements stay consistent through 2050, per the policies in place or proposed as of December 2020 (for AEPS 2022 requirements and for RGGI 2030 requirements). Total in-state electricity generation is projected to decrease from 220,997 GWh in 2020 to 162,027 GWh in 2050 as a result of energy efficiency improvements that reduce consumption, partly driven by Act 129.

As of 2020, natural gas has overtaken nuclear as the largest fuel source for electricity generation in Pennsylvania. Under the BAU scenario, natural gas is expected to continue growing as the primary fuel source for electricity generation through 2050 when it will produce over 90% of Pennsylvania's electricity. Nuclear-based generation is projected to be completely phased out by 2035. The primary driver for phasing out nuclear is low power prices, primarily low gas prices in Pennsylvania. Even with the RGGI 2030 cap held constant in the BAU, prices are not significant enough to provide material support to nuclear units. However, without the RGGI cap in place, gas generation may have increased more after 2035 in the BAU modeling, raising emissions more than is currently projected by 2050. Figure 10 shows the historical and projected fuel mix of electricity generated in Pennsylvania from 2000 through 2050 (BAU scenario).

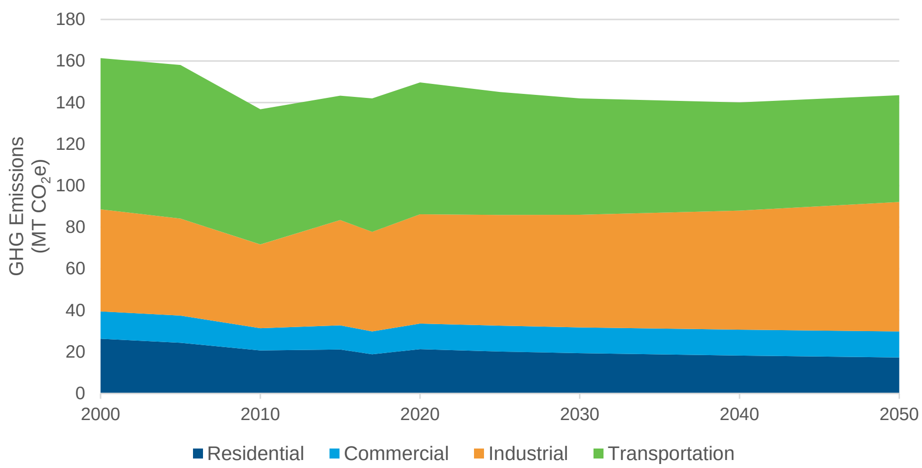
Figure 10: BAU Electricity Generation Mix Over Time



Emissions from direct fuel consumption for residential, commercial, industrial, and transportation uses, which make up the largest percentage of emissions in Pennsylvania (55% in 2020), are projected to decrease by 9%, from 158.1 $MTCO_2e$ in 2005 to 143.6 $MTCO_2e$ in 2050. Emissions from fuel consumption for transportation, residential, and commercial uses each decrease by about 27% through 2050, contributing to lower emission levels. These reductions are likely a result of increased energy efficiency (e.g., a co-benefit of Act 129), increased transportation fuel efficiency standards, signaling that lower-carbon fuels will make up a larger share of transportation fuels in place of high-carbon fuels (e.g., motor gasoline), and that energy efficiency improvements will result in reduced fuel consumption for residential uses (e.g., heating). These decreases are based on projections from the 2020 Annual Energy Outlook (AEO) Reference Case. Industrial emissions from direct fuel consumption are projected to increase from 46.7 $MTCO_2e$ in 2005 to 62.3 $MTCO_2e$ in 2050, driven mainly by economic growth indicators that are included in the Annual Energy Outlook (AEO) Reference Case (2020).

Figure 11 shows projected emissions from direct fuel consumption (non-electricity) by sector through 2050. In line with the GHG accounting approach in the state inventory, emissions from electricity consumption are not included in the BAU totals as that would result in double-counting with the emissions from electricity production included.

Figure 11: Emissions from Direct Fuel Consumption (Non-Electricity) by Sector, 2000-2050



Fugitive emissions from energy production, which includes CH_4 emissions from coal mining and natural gas and oil systems, are projected to increase from 20.6 $MTCO_2e$ in 2020 to 22.7 $MTCO_2e$ in 2050, mainly driven by continued growth in natural gas production. Despite continued decreases in coal production (driven by market preferences), the concurrent increase in natural gas production will lead to a net increase of fugitive emissions from these fuel sources.

Non-energy emissions from industrial processes (e.g., iron and steel production, cement manufacturing, and the use of ODS substitutes) are projected to decline 52% from 2005 levels by 2050. This decline is driven largely by a decrease in emissions from high-GWP gases due to the expected phaseout of HFCs.[6] Industrial emissions of high-GWP gases, including HFCs, PFCs, and SF_6, are projected to fall from a peak of 8.4 $MTCO_2e$ in 2019 to 0.96 $MTCO_2e$ in 2050. Emissions from other industrial processes are projected to decrease less dramatically, from 9.1 $MTCO_2e$ in 2005 to 5.6 $MTCO_2e$ in 2050.

Agricultural emissions increase very little across the time series, from 7.6 $MTCO_2e$ in 2005 to 7.7 $MTCO_2e$ in 2050. Waste emissions remain fairly constant across the time series, decreasing slightly from 5.1 $MTCO_2e$ in 2005 to 4.6 $MTCO_2e$ in 2020 before increasing to 6.1 $MTCO_2e$ in 2050 due to increases in both municipal solid waste and wastewater emissions.

[6] As required in the AIM Act of 2020.

2.1.1 Methodology

The BAU scenario was modeled using a few key datasets to estimate GHG emissions, based on activity data, trends, and policies within the Commonwealth of Pennsylvania. The BAU estimates do not include additional GHG reduction strategies beyond the policies and programs already in place as of September 2020. The BAU uses the following sources for a majority of the input data:

- **EPA's State Inventory Tool (SIT)**: The SIT is used for non-energy projections, including agriculture and waste. SIT provides a combination of population-based forecasts with other state-specific data.
- **State Energy Data System (SEDS)**: Datasets from SEDS are used to provide activity data at the state-level that can be disaggregated by sector. SIT incorporates SEDS data to estimate historical energy consumption and production data.
- **Energy Information Administration (EIA)**: Data from EIA's Annual Energy Outlook (AEO) are used for projections of future emissions. AEO estimates are forecasted at the regional level; these estimates are applied to the state-specific datasets to project energy production and consumption trends.
- **State-specific data**: Specific resources developed or collected within the Commonwealth and by DEP include:
  - MOVES (on-road transportation modeling)
  - Act 129 reports
  - Alternative Energy Portfolio Standard (AEPS) compliance reports
  - Distributed solar data
  - Oil and gas production and systems information
  - Biofuel production data
  - Vehicle registration data
  - U.S. Department of Energy's CHP Installation Database that ICF maintains (contains locational information on CHP systems, loads, etc.)

PA Policies Informing the BAU Scenario:

- **Act 129** – Act 129 requires PA's seven largest electric distribution companies (EDCs) to reduce energy use within their service territory.
- **Alternative Energy Portfolio Standard (AEPS)** – AEPS sets targets for the amount of electricity supplied by PA's EDCs that must come from renewable sources.
- **Regional Greenhouse Gas Initiative (RGGI)** – By joining RGGI, Pennsylvania is obligated to reduce their GHG emissions in coordination with other member states.
- **HFC Phaseout** – PA will phase out HFCs in accordance with EO 2019-01 and the AIM Act.

In addition to these datasets, the BAU also relies on data from ICF's Integrated Planning Model (IPM) to model the electricity sector through 2050.[7]

See Appendix B for additional information about the methodology used to develop the BAU.

[7] ICF's Integrated Planning Model (IPM®) provides true integration of wholesale power, system reliability, environmental constraints, fuel choice, transmission, capacity expansion, and all key operational elements of generators on the power grid in a linear optimization framework. Additional information about IPM can be found here: https://www.icf.com/technology/ipm.

Pennsylvania's Ongoing Energy and Climate Efforts and Commitments

Past and ongoing efforts within Pennsylvania to use energy more efficiently, promote the use of clean energy, and reduce emissions have reduced emissions over time and will help ensure the goal of reducing net GHG emissions by 26% from 2005 levels is met.

Pennsylvania has implemented or committed to numerous energy and environmental programs and policies since the early 1990s. Some of the most notable and ongoing examples include the Alternative Energy Portfolio Standard (AEPS) (2004), Pennsylvania Climate Change Act (2008), Energy Efficiency and Conservation Program (2008), Act 30: Commercial Property Assessed Clean Energy Program (C-PACE) (2017), Act 40: Solar Renewable energy Credits (2017), and joining RGGI (2019). While these efforts began as a way to deregulate the electricity markets and establish standards for work, they evolved to emphasize a transition to cleaner and renewable sources of energy. Listed below are a number of ongoing climate efforts.

- **GreenGov Council** – helps incorporate environmentally sustainable practices into the Commonwealth's policy, planning, operations, procurement, and regulatory functions. It promotes best practices and energy efficiency, including solar purchase for state buildings.
- **Methane regulations** – reduces emissions from natural gas well sites, compressor stations and along pipelines, to not only contribute to climate change mitigation, but also help businesses reduce the waste of a valuable product.
- **Act 129 Phase IV** – expands on phase III, as electric distribution companies incorporate energy efficiency and conservation programs into their operations.
- **DCNR's adaptation plan** – outlines over 100 action steps to increase resiliency against climate change impacts.
- **PennDOT's vulnerability study** – helps anticipate the impacts of extreme weather events so that transportation funding and resiliency may be prioritized.
- **HFC policy** – includes joining the U.S. Climate Alliance (USCA) to develop HFC requirements based on the USCA model rule.
- **RGGI** – reduces GHG emissions from the power sector while also generating economic growth. It sets a regional cap on emissions from electric power plants.
- **Medium-Duty/Heavy-Duty Vehicles MOU** – advances and accelerates the market for electric medium- and heavy-duty vehicles.
- **EV Roadmap** – identifies strategies to increase the adoption of EVs. The Roadmap identifies near-, mid-, and long-term strategies to incentivize and remove barriers to EV adoption.
- **Driving PA Forward** – creates grants and rebate programs aimed at improving air quality in Pennsylvania by spurring the transition from older, polluting diesel engines to clean engine technologies powered by electricity, compressed natural gas, propane, or clean diesel.

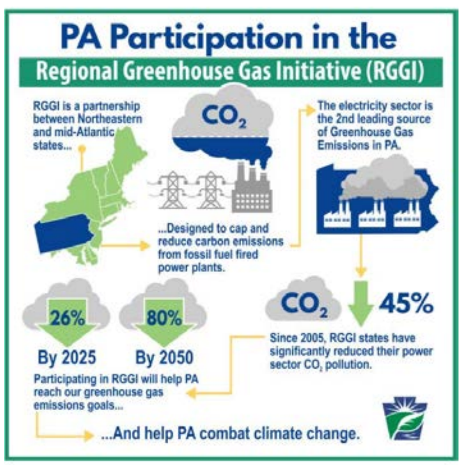


Figure 12. Description of Pennsylvania's participation in RGGI

- **AFIG** – promotes the use of alternative fuels in Pennsylvania. AFIG includes four incentive programs: Alternative Fuel Vehicle Rebate Program, AFIG Grant Program, AFIG Fixing America's Surface Transportation (FAST) Act Infrastructure Program, and Alternative Fuels Technical Assistance Program.
- **PEDA COVID-19 Restart Grant** – offers $1.7 million in grant funding to restart 11 energy projects across Pennsylvania that were disrupted by the COVID-19 pandemic.
- **C-PACE expansion** – provides business property owners with low-interest, long-term loans for clean energy and clean water projects that are repaid as property tax to benefit the community.
- **Green Bank** – information to be provided
- **DEP's Local Climate Action Program** – allows local governments and municipalities to work together to develop GHG inventories and climate action plans.
- **Formation of PA Climate Leadership Academy** – connects with schools to teach and encourage community leadership in order to foster sustainable climate improvements.

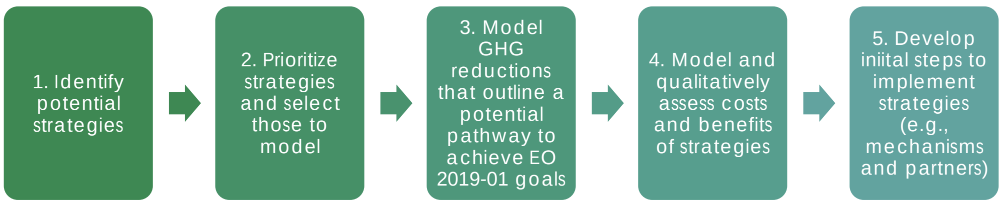
For more information on these and other ongoing efforts, visit DEP's website: https://www.dep.pa.gov. The next section describes additional opportunities for reducing GHG emissions in Pennsylvania.

3 OPPORTUNITIES FOR REDUCING GHG EMISSIONS IN PENNSYLVANIA

GHG Reduction Strategy Analysis

The GHG strategy reductions analysis presented in this section was developed using the process outlined in Figure 13.

Figure 13. GHG Reduction Analysis Approach



3.1.1 Potential Strategies

- The strategies presented in this report are based on six main sources:
    - DEP's knowledge of trending and common strategies used across the state
    - Feedback from the Climate Change Advisory Committee (CCAC)
    - A review of the 2018 Climate Action Plan, including letters from the CCAC
    - A review of the 2021 DEP Clean Energy Programs Plan
    - A review of public survey data from DEP on the 2018 Climate Action Plan
    - ICF's knowledge of trending and common strategies used across the country

3.1.2 Prioritizied Strategies

- Developed prioritization criteria and weights collaboratively with DEP and CCAC
- Criteria include:
    - GHG reduction magnitude
    - ease of implementation (legal, institutional)
    - initial investment required
    - cost effectiveness
    - air quality benefits
    - public health benefits
    - resilience benefits
    - environmental justice and equitable implementation benefits
- Each potential strategy was evaluated on the criteria and given a score
- After strategies were scored, DEP reviewed the potential strategies and selected a subset that were most aligned with the Commonwealths goals, needs, and interests. Of these, DEP worked with ICF to determine which strategies could be modeled for GHG reductions, costs and benefits based on available data.
- The table below summarizes the selected strategy names and descriptions, identifies whether a strategy is quantified or not, and indicates the expected implementation timeframe of each.
    - Time frames are defined as follows:

- Near-term: 1 to 5 years
- Mid-term: 5 to 10 years
- Long-term: 10+ years

- All strategies are described in greater details in the following sections.

Table 3. Summary of GHG Reduction Strategies by Sector

Sector	GHG Reduction Strategy	Expected Implementation Timeframe	Quantified GHG Reductions, Costs and Benefits
Residential and Commercial (R&C) Buildings	Support energy efficiency through building codes	Near-term	Yes
R&C Buildings	Improve residential and commercial energy efficiency (electricity)	Near-term	Yes
R&C Buildings	Improve residential and commercial energy efficiency (gas)	Near-term	Yes
R&C Buildings	Incentivize building electrification	Long-term	Yes
R&C Buildings	Introduce state appliance efficiency standards	Mid-term	No
R&C Buildings	Take actions to promote and advance C-PACE financing and other tools for Net Zero Buildings and high-performance buildings	Near-term	No
Transportation	Increase fuel efficiency of all light duty vehicles and reduce vehicle miles traveled for single occupancy vehicles	Medium-term	Yes
Transportation	Implement the multi-state medium-and heavy-duty zero-emission vehicle memorandum of understanding	Long-term	Yes
Transportation	Increase adoption of light-duty electric vehicles	Mid-term	Yes
Transportation	Implement a Low Carbon Fuel Standard	Mid-term	Yes
Industrial	Increase industrial energy efficiency and fuel switching	Near-term	Yes
Fuel Supply	Increase production and use of biogas/renewable gas	Mid-term	Yes
Fuel Supply	Incentivize and increase use of distributed Combined Heat and Power	Near-term	Yes
Fuel Supply	Reduce methane emissions across oil and natural gas systems	Mid-term	Yes
Electricity Generation	Maintain nuclear generation at current levels	Near-term	Yes
Electricity Generation	Create a carbon emissions free grid	Long-term	Yes

Commented [D6]: Note – strategies not modeled will be included in the next iteration of the CAP report

Agriculture	Use programs, tools, and incentives to increase energy efficiency for agriculture	Near-term	Yes
Agriculture	Provide trainings and tools to implement agricultural best practices	Mid-term	Yes
LULUCF	Land and forest management for natural sequestration and increased urban green space	Mid-term	Yes
Waste	Reduce food waste	Near-term	No
Waste	Reduce waste generated by citizens and businesses and expand beneficial use of waste	Near-term	No

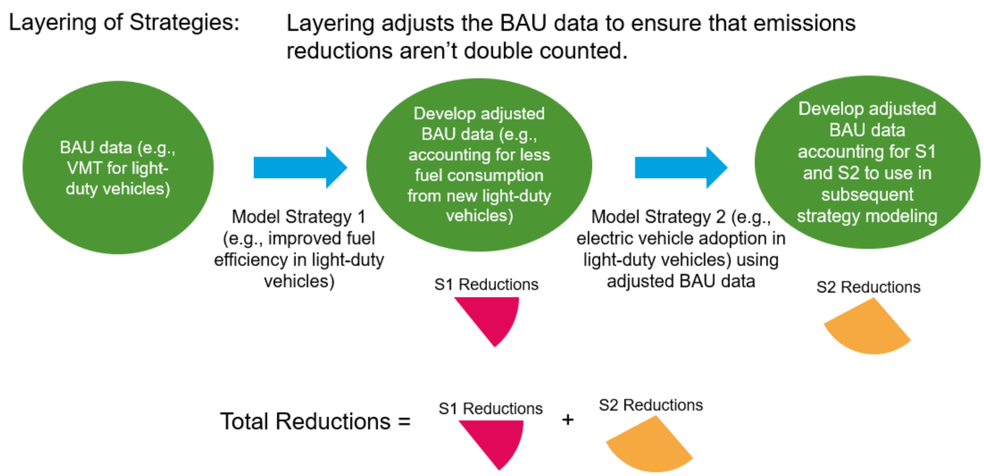
3.1.3 Modeling and Analysis Approach

GHG Reduction Accounting Approach

The GHG accounting approach used in modeling GHG reductions for this plan is aligned with the GHG accounting approach used in the GHG inventory and BAU projections, and accounts for the interactions between various strategies to ensure accurate accounting. Key aspects of this accounting approach include:

- Reductions in GHG emissions as a result of reductions in direct fuel use for all energy other than electricity is represented in the end use sector (i.e., residential, commercial, industrial, and transportation).
    - Note: Reductions in GHG emissions as a result of changes in end use electricity consumption are not included in totals to avoiding overlapping GHG reductions from different sectors and actions (i.e., "double counting"). This information is reported informally and uses a marginal emission factor for energy efficiency and distributed energy (i.e., CHP) informationally reported reductions from electricity use changes. See also below on GHG emissions for electricity generation.
- Reductions in GHG emissions as a result of changes in both electricity consumptions and the generation mix are accounted for in the electricity generation sectors. GHG emissions from electricity generations are modeled in a two-step process:
    - Estimate changes in electric load as a result of all strategies that impacts load (e.g., energy efficiency, electrification).
    - Feed the load changes over time into the Integrated Planning Model© with policy assumptions to estimate generation mixes over time.
- Layering the impacts of certain strategies to avoid over-estimating reductions, as outlined in Figure 14. Layering the impacts of strategies indicates the assumed order of implementation in which strategies occur to account for the interactions between them (e.g., a strategy that targets improving fuel efficiency standards may reduce overall fuel consumption, and a second strategy that targets electric vehicle adoption should incorporate the impacts of more fuel-efficient vehicles on the road at the outset to appropriately assess the impact on GHG emissions).

Figure 14. Approach to Layering Strategies



Economic Benefits and Costs

- Describe how strategies may have economic benefits
- Explain economic modeling methodology and metrics
- Allude to the economic results being included in each strategy
- Define metrics used

Co-Benefits and Costs

- Describe what co-benefits are and connect them to GHG reduction strategies
- Co-benefits can include improved air quality, health outcomes, equity, and more
- Some may be direct co-benefits, others may be indirect
- Explain how considering and quantifying co-benefits provides a more holistic approach and better informs decision-making
- Describe approaches to identifying and quantifying co-benefits
- Define metrics used
- High potential for graphics to describe the concept

Equity

- Define equity and connect the concept to GHG reduction strategies
- Describe how strategies can improve equity
- Describe how equity was considered and integrated into the strategies
- Define metrics used

Pennsylvania's Pathway to 2050

- List key takeaways upfront
- Summary of quantitative and qualitative impacts on metrics across all sectors and strategies:
    - energy use,

    - GHG reduction potential,
    - air quality,
    - health,
    - equity, and
    - economic effects
- Indicate progress toward achieving 2025 and 2050 GHG reduction goals
- Note any high-impact results
- Include cumulative results and accompanying charts/table (examples below)
- E.g., a graphic that breaks down reductions by sector for the BAU as compared to the 80x50 scenario
- E.g., a "story-telling chart" showing different pathway options (last example), this can also be reiterated in the implementation section to talk about phasing, or built on in some way there

Figure 15. GHG Reductions from Strategies in 2050, Compared to BAU (MTCO₂e)

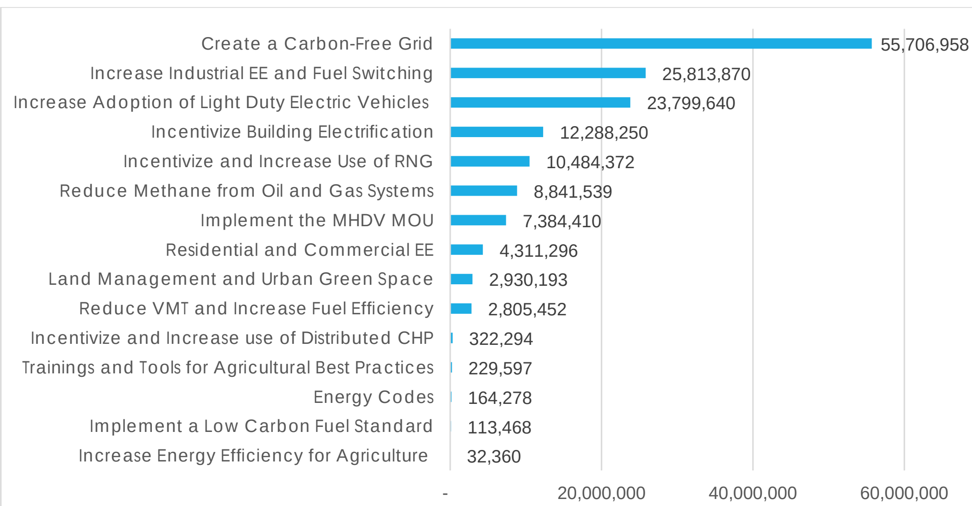
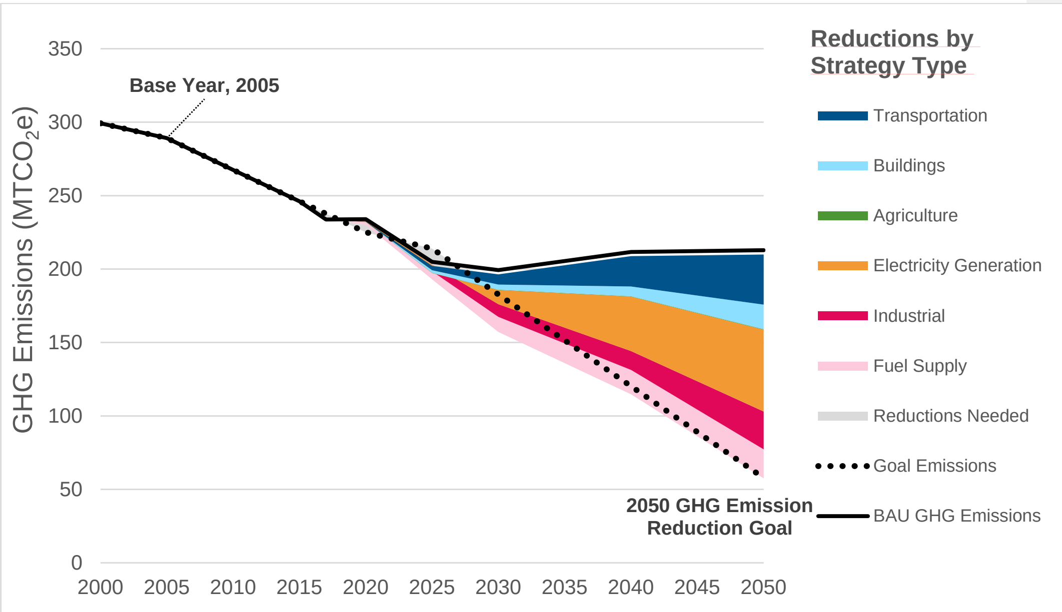


Figure 16. GHG Reductions by Strategy, 2000-2050 ($MTCO_2e$)



Residential and Commercial Buildings

- Define the sector and its scope
- Describe the context of the sector in Pennsylvania
- Note that this is for residential and commercial buildings, as well as institutional building like hospitals and schools.
- Clearly state that we are only reporting these electricity emissions for informational purposes from res/com—we will report costs, but we are not attributing electric emissions here.
- Add in HFCs for buildings either in the modeling or the discussion
- Summary of quantitative and qualitative metrics for sector and by strategy: energy, GHG reduction potential, air quality benefits, health benefits, equity, and economic benefits
- Overview of strategies and overall expected results of implementing them
- E.g., there are X strategies, which include 1, 2, and 3. Together, it is projected that they will reduce emissions in the building sector by X amount by X year
- Include stacked chart showing annual GHG reductions compare to BAU for 2025 and 2050 (show reductions as negative)
- Include table that lists each strategy and the annual GHG reduction in 2025, in 2050, and the cost/tCO2 Reduced

Support Energy Efficiency Through Building Codes

This strategy includes adopting the most current building codes, enforcing existing codes, encouraging local adoption of stretch codes, and educating and training code officials and inspectors on code enforcement. To ensure effective compliance with building codes, this strategy also includes steps to educate municipalities on their ability to implement and require codes beyond the State Code, including "stretch codes" such as International Green Construction Code (IgCC), Zero Code and NetZero Codes.

Environmental benefits and costs

- GHG reductions
  - Note which GHGs will be reduced total reductions
- Energy changes
- Cost per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
  - Include a likely timeframe for implementation
- Describe actors and partners
  - Include what level(s) of government would implement and specifically who would be responsible for implementing
  - State government
- Offer considerations or actions to ensure equitable implementation and outcomes
- Discuss phasing
- Note challenges and opportunities to implementation
  - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
  - Describe possible solutions to overcome challenges
  - Describe any opportunities and how to best take advantage of them

Annual GHG Emissions Reduced in 2025[8]	24,444 $MTCO_2e$
Annual GHG Emissions Reduced in 2050	164,278 $MTCO_2e$
Annual Energy Reduced in 2050	654 GWH of electricity 2,975 Bbtu of gas
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	\$XXX/$MTCO_2e$
Gross State Product	\$XXX million
Disposable Income	\$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

[8] Reductions are compared to the BAU estimates from the respective year.

- Note any enabling technologies

Improve Residential and Commercial Energy Efficiency (Electricity)

This strategy includes several actions to improve residential and commercial energy efficiency by requiring increased residential and commercial energy efficiency improvements targeted at kWh savings, either within the existing framework of or a modified framework of Act 129 (e.g., increasing savings targets and removing spending caps).

For Act 129, this includes increasing the low- to moderate-income (LMI) share of spending and reforming cost-effectiveness tests to support more LMI focus, and adding climate mitigation and resilience benefits to cost effectiveness tests. To enhance Act 129 effectiveness and increase savings, incentives and education should leverage programs like Low Income Home Energy Assistance Program (LIHEAP) and Weatherization Assistance Program (WAP).

Beyond Act 129, this strategy includes statewide programs targeted at reducing electricity use in large commercial buildings through a gradually expanding Commercial Building Energy Performance Program. Such a program could begin with energy benchmarking of large facilities, and grow to include retro-commissioning or energy efficiency requirements.

Environmental benefits and costs

- GHG reductions
  - List major GHGs addressed by this strategy.
- Energy changes
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
  - Include a likely timeframe for implementation

Annual GHG Emissions Reduced in 2025	Not included in totals[9]
Annual GHG Emissions Reduced in 2050	Not included in totals[10]
Annual Energy Reduced in 2050	21,948 GWH
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	$XXX/$MTCO_2e$
Gross State Product	$XXX million
Disposable Income	$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

[9] GHG emissions associated with decreased electricity consumption from this strategy are not included in totals – a generation-based GHG accounting approach is used in line with the state inventory.

[10] GHG emissions associated with decreased electricity consumption from this strategy are not included in totals – a generation-based GHG accounting approach is used in line with the state inventory.

- Describe actors and partners
    - Include what level(s) of government would implement and specifically who would be responsible for implementing
    - State government
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
    - Many environmental justice or low-income communities would not be financially benefited by this strategy, and careful implementation would be required to avoid increasing financial burdens and disparities (for example, expansion of programs like LIHEAP).
- Discuss phasing
- Note challenges and opportunities to implementation
    - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
    - Describe possible solutions to overcome challenges
    - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

Improve Residential and Commercial Energy Efficiency (Gas)

Annual GHG Emissions Reduced in 2025	1,365,613 $MTCO_2e$
Annual GHG Emissions Reduced in 2050	4,311,296 $MTCO_2e$
Annual Energy Reduced in 2050	80,973 Bbtu of gas
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	\$XXX/$MTCO_2e$
Gross State Product	\$XXX million
Disposable Income	\$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

This strategy includes creating a new energy efficiency program focused on reducing gas consumption that is similar to the voluntary gas demand side management (DSM) programs already in place with some Pennsylvania gas utilities. This strategy specifically includes statewide programs targeted at reducing natural gas use in large commercial buildings through a gradually expanding Commercial Building Energy Performance Program. This type of program includes energy benchmarking of large facilities, and grow to include retro-commissioning or energy efficiency requirements. It also includes an allocation of a certain portion of funds for LMI individuals, and reform cost-effectiveness tests, e.g., by adding climate mitigation and resilience benefits to the tests.

Environmental benefits and costs

- GHG reductions
  - List major GHGs addressed by this strategy.
- Energy changes
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
  - Include a likely timeframe for implementation
- Describe actors and partners
  - Include what level(s) of government would implement and specifically who would be responsible for implementing
  - State government
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
- Discuss phasing
- Note challenges and opportunities to implementation
  - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change

    - Describe possible solutions to overcome challenges
    - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

Incentivize Building Electrification

This strategy includes incentivizing building electrification (e.g., heating and hot water) for the residential and commercial sectors. It also includes a new program focused on beneficial electrification, possibly modeled on the New York Clean Heat program. This includes incentives for converting fuel oil and natural gas to electricity in existing buildings and electrification of new buildings where there are large natural gas infrastructure costs or where fuel oil is the alternative.

Environmental benefits and costs

- GHG reductions
  - List major GHGs addressed by this strategy.
- Energy changes
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable Income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
  - Include a likely timeframe for implementation
- Describe actors and partners
  - Include what level(s) of government would implement and specifically who would be responsible for implementing
  - State government
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
- Discuss phasing
- Note challenges and opportunities to implementation
  - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
  - Describe possible solutions to overcome challenges
  - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

Annual GHG Emissions Reduced in 2025	483,807 $MTCO_2e$
Annual GHG Emissions Reduced in 2050	12,288,250 $MTCO_2e$
Annual Energy Reduced in 2050	-181,905 GWH of electricity (increase) 222,699 Bbtu of gas
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	$XXX/$MTCO_2e$
Gross State Product	$XXX million
Disposable Income	$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

Transportation

- Define the sector and its scope
- Describe the context of the sector in Pennsylvania
- Clearly state that we are only reporting these electricity emissions for informational purposes from trans—we will report costs, but we are not attributing electric emissions here.
- Summary of quantitative and qualitative metrics for sector and by strategy: energy, GHG reduction potential, air quality benefits, health benefits, equity, and economic benefits
- Overview of strategies and overall expected results of implementing them
- E.g., there are X strategies, which include 1, 2, and 3. Together, it is projected that they will reduce emissions in the building sector by X amount by X year
- Include stacked chart showing annual GHG reductions compare to BAU for 2025 and 2050 (show reductions as negative)
- Include table that lists each strategy and the annual GHG reduction in 2025, in 2050, and the cost/tCO2 Reduced

Transportation and Climate Initiative

- DEP is involved in the development, outreach, and engagement of the program
- TCI is cap and invest program, builds on and can work with other options for reducing emissions from the transportation sector

Increase fuel efficiency of all light duty vehicles and reduce vehicle miles traveled for single occupancy vehicles

Annual GHG Emissions Reduced in 2025	571,524 $MTCO_2e$
Annual GHG Emissions Reduced in 2050	2,805,452 $MTCO_2e$
Annual Energy Reduced in 2050	38,573 Bbtu of gasoline
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	\$XXX/$MTCO_2e$
Gross State Product	\$XXX million
Disposable Income	\$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

This strategy includes a reduction of vehicle miles traveled (VMT) for single-occupancy vehicles by implementing travel demand strategies such as shifting travel time, mode choice, and route, increasing the frequency of telecommuting. It also includes increased fuel efficiency standards. These efforts are paired with land-use and development policies that develop and promote sustainable transportation modes (walking, biking, transit, carpool) in existing densely populated urban areas, followed by expansion to underserved communities outside of urban centers in the medium and long term.

Environmental benefits and costs

- GHG reductions
    - List major GHGs addressed by this strategy.
- Energy changes
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable Income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
    - Include a likely timeframe for implementation
- Describe actors and partners
    - Include what level(s) of government would implement and specifically who would be responsible for implementing
    - State government
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
    - More public transit and less congestion on roads actually does benefit LMI as those population segments are statistically more likely to a) take transit and b) if they drive, work jobs that have rigid schedules.

- Discuss phasing
- Note challenges and opportunities to implementation
    - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
    - Describe possible solutions to overcome challenges
    - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

Implement the Multi-state Medium-and Heavy-duty Zero-emission Vehicle Memorandum of Understanding

This strategy includes implementing the multi-state medium- and heavy-duty zero-emission vehicle memorandum of understanding (MHD ZEV MOU), of which the State of Pennsylvania is a co-signatory. The goal of the MOU is to reach net zero emissions from MHDVs by 2050. This target would be achieved through a mix of fuel switching to electric and other zero-emission vehicles such as fuel cell electric vehicles (FCEV), and would eliminate vehicles that have a disproportionate impact on air quality due to diesel emissions and/or that have a relatively low fuel economy. Potential actions (as stated in the MOU) may include:

- Financial vehicle and infrastructure incentives.
- Non-financial vehicle and infrastructure incentives.
- Actions to encourage public transit and public fleets to deploy zero emission MHDVs.
- Effective infrastructure deployment strategies.
- Funding sources and innovative financing models to support incentives and other market-enabling programs.
- Leveraging environmental and air quality benefits associated with the adoption of the California Advanced Clean Trucks rule under Section 177 of the Clean Air Act.
- Coordinated outreach and education to public and private MHDV fleet managers.
- Utility actions to promote zero emission MHDVs, such as electric distribution system planning, beneficial rate design and investment in "make-ready" charging infrastructure.
- Measures to foster electric truck use in densely populated areas.
- Addressing vehicle weight restrictions that are barriers to zero emission MHDV deployment.
- Uniform standards and data collection requirements.

Environmental benefits and costs

- GHG reductions
    - List major GHGs addressed by this strategy.
- Energy changes
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable Income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:

Annual GHG Emissions Reduced in 2025	291,395 $MTCO_2e$
Annual GHG Emissions Reduced in 2050	7,384,410 $MTCO_2e$
Annual Energy Reduced in 2050	91,732 Bbtu of distillate fuel oil -6,132 GWh of electricity (increase)
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	$XXX/$MTCO_2e$
Gross State Product	$XXX million
Disposable Income	$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
    - Include a likely timeframe for implementation
- Describe actors and partners
    - Include what level(s) of government would implement and specifically who would be responsible for implementing
    - State government
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
- Discuss phasing
- Note challenges and opportunities to implementation
    - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
    - Describe possible solutions to overcome challenges
    - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

Increase Adoption of Light-Duty Electric Vehicles

This strategy includes increasing the adoption of light-duty electric passenger vehicles (including private and municipal fleet vehicles) by following the Pennsylvania EV Roadmap, using a ZEV mandate, providing education and outreach, and offering additional or modified incentives through AFIG, the Alternative Fuel Vehicle (AFV) Rebate, and the Driving Pennsylvania Forward program. This strategy also includes approaches for providing access to electric vehicles and charging infrastructure in low-income communities, multi-family units, and workplaces through ad-hoc programs.

Environmental benefits and costs

- GHG reductions
  - List major GHGs addressed by this strategy.
- Energy changes
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable Income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
  - Include a likely timeframe for implementation
- Describe actors and partners
  - Include what level(s) of government would implement and specifically who would be responsible for implementing
  - State government
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
- Discuss phasing
- Note challenges and opportunities to implementation
  - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
  - Describe possible solutions to overcome challenges
  - Describe any opportunities and how to best take advantage of them

Annual GHG Emissions Reduced in 2025	1,225,113 $MTCO_2e$
Annual GHG Emissions Reduced in 2050	23,799,640 $MTCO_2e$
Annual Energy Reduced in 2050	327,301 Bbtu of gasoline -33,178 GWH of electricity (increase)
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	\$XXX/$MTCO_2e$
Gross State Product	$XXX million
Disposable Income	$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

- Note any enabling technologies

Implement a Low Carbon Fuel Standard (LCFS)

This strategy includes decreasing the carbon intensity of transportation fuels and provide an increased supply and range of alternative fuels through a system of credits, similar to the California LCFS Program. This expands on the ethanol and biodiesel requirements already in place in Pennsylvania, and would apply to zero-emission vehicles.

Annual GHG Emissions Reduced in 2025	809,094 $MTCO_2e$
Annual GHG Emissions Reduced in 2050	113,468 $MTCO_2e$
Annual Energy Reduced in 2050	1,866 Bbtu of distillate fuel oil -476 GWH of electricity (increase)
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	\$XXX/$MTCO_2e$
Gross State Product	\$XXX million
Disposable Income	\$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

Environmental benefits and costs

- GHG reductions
    - List major GHGs addressed by this strategy.
- Energy changes
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable Income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
    - Include a likely timeframe for implementation
- Describe actors and partners
    - Include what level(s) of government would implement and specifically who would be responsible for implementing
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
- Discuss phasing
- Note challenges and opportunities to implementation
    - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
    - Describe possible solutions to overcome challenges
    - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

Industrial

- Define the sector and its scope
- Describe the context of the sector in Pennsylvania
- Describe what industrial emissions are comprised of and identify the types of GHGs covered.
- Summary of quantitative and qualitative metrics for sector and by strategy: energy, GHG reduction potential, air quality benefits, health benefits, equity, and economic benefits
- Overview of strategies and overall expected results of implementing them
- E.g., there are X strategies, which include 1, 2, and 3. Together, it is projected that they will reduce emissions in the building sector by X amount by X year
- Include stacked chart showing annual GHG reductions compare to BAU for 2025 and 2050 (show reductions as negative)
- Include table that lists each strategy and the annual GHG reduction in 2025, in 2050, and the cost/tCO2 Reduced

Increase Industrial Energy Efficiency and Fuel Switching

This strategy includes leveraging existing DEP programs (e.g., the Energy Efficiency, Environment, and Economics [E4] Initiative) and implementing the types of actions outlined in the Clean Energy Program Plan developed by DEP's Energy Programs Office. This strategy will rely on broader tools such as virtual trainings and expanded partnerships to reach smaller and hard to access industries. In addition to energy efficiency measures, industrial opportunities that fuel switch from fuel oil to natural gas and measures to switch natural gas to electricity are included in this strategy.

Environmental benefits and costs

- GHG reductions
    - List major GHGs addressed by this strategy.
- Energy changes
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable Income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
    - Include a likely timeframe for implementation
- Describe actors and partners
    - Include what level(s) of government would implement and specifically who would be responsible for implementing
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
- Discuss phasing
- Note challenges and opportunities to implementation
    - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
    - Describe possible solutions to overcome challenges
    - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

Annual GHG Emissions Reduced in 2025	4,277,761 $MTCO_2e$
Annual GHG Emissions Reduced in 2050	25,813,870 $MTCO_2e$
Annual Energy Reduced in 2050	7,467 GWH of electricity 407,242 Bbtu of gas
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	$XXX/$MTCO_2e$
Gross State Product	$XXX million
Disposable Income	$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

Fuel Supply

- Define the sector and its scope
- Describe the context of the sector in Pennsylvania
- Summary of quantitative and qualitative metrics for sector and by strategy: energy, GHG reduction potential, air quality benefits, health benefits, equity, and economic benefits
- Overview of strategies and overall expected results of implementing them
- E.g., there are X strategies, which include 1, 2, and 3. Together, it is projected that they will reduce emissions in the building sector by X amount by X year
- Include stacked chart showing annual GHG reductions compare to BAU for 2025 and 2050 (show reductions as negative)
- Include table that lists each strategy and the annual GHG reduction in 2025, in 2050, and the cost/tCO2 Reduced
- Present each strategy separately using the strategy template

Increase Production and Use of Biogas/Renewable Gas

This strategy includes increases in the production and use of biogas/renewable gas from sources such as coal mines, agriculture, wastewater, and landfills. This strategy considers the potential for renewable gas and specific applications within Pennsylvania and regionally across a number of feedstocks, as identified in the 2019 American Gas Foundation renewable natural gas (RNG) report, Penn State University's RNG analysis, and ICF's Pennsylvania RNG database. Fuels will be supplied through the existing pipeline network and will supply end uses, not including power generation.

Annual GHG Emissions Reduced in 2025	1,103,662 $MTCO_2e$
Annual GHG Emissions Reduced in 2050	10,484,372 $MTCO_2e$
Annual Energy Reduced in 2050	Not calculated
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	$XXX/$MTCO_2e$
Gross State Product	$XXX million
Disposable Income	$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

Environmental benefits and costs

- GHG reductions
  - List major GHGs addressed by this strategy.
- Energy changes
- NPV per ton of GHG reduced

Economic benefits and **costs**

- NPV
- Jobs
- Disposable Income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
  - Include a likely timeframe for implementation
- Describe actors and partners
  - Include what level(s) of government would implement and specifically who would be responsible for implementing
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
- Discuss phasing
- Note challenges and opportunities to implementation
  - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
  - Describe possible solutions to overcome challenges
  - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

Incentivize and Increase Use of Distributed Combined Heat and Power (CHP)

This strategy includes incentivizing and increasing the use of distributed CHP with microgrids, particularly for high-value applications such as critical facilities (e.g., hospitals) and industrial facilities.

Environmental benefits and costs

- GHG reductions
    - List major GHGs addressed by this strategy.
- Energy changes
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable Income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
    - Include a likely timeframe for implementation
- Describe actors and partners
    - Include what level(s) of government would implement and specifically who would be responsible for implementing
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
- Discuss phasing
- Note challenges and opportunities to implementation
    - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
    - Describe possible solutions to overcome challenges
    - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

Annual GHG Emissions Reduced in 2025	39,270 MTCO_2e
Annual GHG Emissions Reduced in 2050	322,294 MTCO_2e
Annual Energy Reduced in 2050	8,764 GWH of electricity -48,906 Bbtu of gas (increase)
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX MTCO_2e
Net Present Value	XXX/MTCO_2$e
Gross State Product	$XXX million
Disposable Income	$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

Reduce Methane Emissions Across Oil and Natural Gas Systems

This strategy includes the implementation of practices to reduce methane emissions from upstream and midstream oil and gas operations. This strategy reflects reductions of methane emissions as a co-benefit of the ongoing rulemaking to curb VOC emissions from oil and gas operations.[11] It also includes voluntary mitigation technologies that would be implemented across operations to further reduce methane emissions beyond regulatory requirements.

Annual GHG Emissions Reduced in 2025	4,320,850 $MTCO_2e$
Annual GHG Emissions Reduced in 2050	8,841,539 $MTCO_2e$
Annual Energy Reduced in 2050	Not calculated
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	$XXX/$MTCO_2e$
Gross State Product	$XXX million
Disposable Income	$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

Environmental benefits and costs

- GHG reductions
    - List major GHGs addressed by this strategy.
- Energy use changes
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable Income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
    - Include a likely timeframe for implementation
- Describe actors and partners
    - Include what level(s) of government would implement and specifically who would be responsible for implementing
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
- Discuss phasing
- Note challenges and opportunities to implementation

[11] This rulemaking establishes requirements for storage vessels, natural gas driven pneumatic controllers, natural gas-driven diaphragm pumps, reciprocating and centrifugal compressors, and fugitive emissions components. For more information see: https://www.dep.pa.gov/Business/Air/pages/methane-reduction-strategy.aspx

  - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
  - Describe possible solutions to overcome challenges
  - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

Electricity Generation

- Define the sector and its scope
- Describe the context of the sector in Pennsylvania
- Summary of quantitative and qualitative metrics for sector and by strategy: energy, GHG reduction potential, air quality benefits, health benefits, equity, and economic benefits
- Overview of strategies and overall expected results of implementing them
- E.g., there are X strategies, which include 1, 2, and 3. Together, it is projected that they will reduce emissions in the building sector by X amount by X year
- Include stacked chart showing annual GHG reductions compare to BAU for 2025 and 2050 (show reductions as negative)
- Include table that lists each strategy and the annual GHG reduction in 2025, in 2050, and the cost/tCO2 Reduced

Maintain Nuclear Generation at Current Levels

This strategy includes implementing a policy to maintain nuclear generation at current levels. This would assume an 80-year lifetime extensions for plants currently in operation; all plants currently in operation would stay online through 2050 at least with this extension. Nuclear generation is also incorporated into the carbon emissions free grid strategy below, therefore the costs and benefits associated with this strategy are incorporated in the carbon free grid strategy.

Environmental benefits and costs

- GHG reductions
  - List major GHGs addressed by this strategy.
- Energy changes
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable Income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
  - Include a likely timeframe for implementation
- Describe actors and partners
  - Include what level(s) of government would implement and specifically who would be responsible for implementing

- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
- Discuss phasing
- Note challenges and opportunities to implementation
    - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
    - Describe possible solutions to overcome challenges
    - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

Create a Carbon Emissions Free Grid

This strategy includes expanding the Alternative Energy Portfolio Standard (AEPS) to achieve a carbon free grid. Tier 1 targets and the solar carve out are expanded, and additional eligible energy sources are added including nuclear, storage, and fossil with carbon capture and sequestration. Tier 2 sources are maintained as part of the portfolio of options to meet the 100% target. To implement this successfully, additional efforts will need to be employed, such as strategies to expand the development of solar and wind projects across the Commonwealth (both grid-scale and distributed), legislation to help develop a robust solar industry at the distributive- and grid-level, and strategies that increase the value of solar renewable energy credits (SRECs).

Annual GHG Emissions Reduced in 2025	-5,559,548 $MTCO_2e$ (increase)[12]
Annual GHG Emissions Reduced in 2050	55,706,958 $MTCO_2e$
Annual Energy Reduced in 2050	Not calculated
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	$XXX/$MTCO_2e$
Gross State Product	$XXX million
Disposable Income	$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

Environmental benefits and costs

- GHG reductions
    - List major GHGs addressed by this strategy.
- Energy changes
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable Income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
    - Include a likely timeframe for implementation
- Describe actors and partners
    - Include what level(s) of government would implement and specifically who would be responsible for implementing
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations

[12] A net increase in emissions from this strategy occurs in 2025 because, in the Policy Scenario, the electric load is higher than in the BAU scenario for that year and is met primarily by fossil fuel generation. As the

- Discuss phasing
- Note challenges and opportunities to implementation
    - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
    - Describe possible solutions to overcome challenges
    - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

electricity grid becomes cleaner through increased reliance on renewable fuels for generation (i.e., in later years in the analysis), net reductions in emissions from electric power generation are seen.

Agriculture

- Define the sector and its scope
- Describe the context of the sector in Pennsylvania
- Summary of quantitative and qualitative metrics for sector and by strategy: energy, GHG reduction potential, air quality benefits, health benefits, equity, and economic benefits
- Overview of strategies and overall expected results of implementing them
- E.g., there are X strategies, which include 1, 2, and 3. Together, it is projected that they will reduce emissions in the building sector by X amount by X year
- Include stacked chart showing annual GHG reductions compare to BAU for 2025 and 2050 (show reductions as negative)
- Include table that lists each strategy and the annual GHG reduction in 2025, in 2050, and the cost/tCO2 Reduced

Use Programs, Tools, and Incentives to Increase Energy Efficiency for Agriculture

This strategy includes programs, tools, and incentives to increase energy efficiency for agricultural end uses such as refrigeration, ventilation, and lighting.

Environmental benefits and costs

- GHG reductions
  - List major GHGs addressed by this strategy.
- Energy changes
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable Income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
  - Include a likely timeframe for implementation
- Describe actors and partners
  - Include what level(s) of government would implement and specifically who would be responsible for implementing
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
- Discuss phasing
- Note challenges and opportunities to implementation
  - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
  - Describe possible solutions to overcome challenges
  - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

Annual GHG Emissions Reduced in 2025	9,609 $MTCO_2e$
Annual GHG Emissions Reduced in 2050	32,360 $MTCO_2e$
Annual Energy Reduced in 2050	96 GWh of electricity 256 BBtu of distillate fuel oil
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	$XXX/$MTCO_2e$
Gross State Product	$XXX million
Disposable Income	$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

Provide Trainings and Tools to Implement Agricultural Best Practices

This strategy includes trainings and tools to implement agricultural best practices, such as those focused on no-till farming practices, integrated farm management and conservation planning, and soil management. Practices could include rotational grazing, silvopasture, and organic and regenerative agricultural methods. This strategy also includes researching crops that will be most appropriate for future climate conditions.

Environmental benefits and costs

- GHG reductions
    - List major GHGs addressed by this strategy.
- Energy changes
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable Income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
    - Include a likely timeframe for implementation
- Describe actors and partners
    - Include what level(s) of government would implement and specifically who would be responsible for implementing
    - State government
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
- Discuss phasing
- Note challenges and opportunities to implementation
    - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
    - Describe possible solutions to overcome challenges
    - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

Annual GHG Emissions Reduced in 2025	145,799 $MTCO_2e$
Annual GHG Emissions Reduced in 2050	229,597 $MTCO_2e$
Annual Energy Reduced in 2050	75 Bbtu natural gas 237 Bbtu of distillate fuel oil
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	$XXX/$MTCO_2e$
Gross State Product	$XXX million
Disposable Income	$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

Land Use and Forestry (LULUCF)

- Define the sector and its scope
- Describe the context of the sector in Pennsylvania
- Summary of quantitative and qualitative metrics for sector and by strategy: energy, GHG reduction potential, air quality benefits, health benefits, equity, and economic benefits
- Overview of strategies and overall expected results of implementing them
- E.g., there are X strategies, which include 1, 2, and 3. Together, it is projected that they will reduce emissions in the building sector by X amount by X year
- Include stacked chart showing annual GHG reductions compare to BAU for 2025 and 2050 (show reductions as negative)
- Include table that lists each strategy and the annual GHG reduction in 2025, in 2050, and the cost/tCO2 Reduced

Land and Forest Management for Natural Sequestration and Increased Urban Green Space

This strategy include managing and increasing forest cover, particularly of oak-hickory forest, through a reduction of forest removal from 130-yr rotation, and additional converting abandoned mined lands to forests.

Holder for paragraph on other sequestration options and uncertainty discussion (e.g., discussion of increasing timber stocking on existing forest land."Forests and harvested wood products uptake the equivalent of more than 14% of economy-wide CO_2 emissions in the United States annually, and there is potential to increase carbon sequestration capacity by ~20% (−187.7 million metric tons [MT] CO_2 ±9.1 MT CO_2) per year by fully stocking all understocked productive forestland.")

Annual GHG Emissions Reduced in 2025	2,698,407 $MTCO_2e$
Annual GHG Emissions Reduced in 2050	2,930,193 $MTCO_2e$
Cost/(Benefit) per ton of GHG Reduced	XXX,XXX $MTCO_2e$
Net Present Value	$XXX/$MTCO_2e$
Gross State Product	$XXX million
Disposable Income	$XXX million
Jobs	X,XXX jobs
Air Quality	X
Public Health	X
Social Equity	X

Environmental benefits and costs

- GHG reductions
  - List major GHGs addressed by this strategy.
- NPV per ton of GHG reduced

Economic benefits and costs

- NPV
- Jobs
- Disposable Income
- Gross State Product (GSP)

Social benefits and costs

- Air quality:
- Public health:
- Environmental justice and equity:
- Resiliency:

Implementation Considerations

- Describe necessary actions to implement the strategy
  - Include a likely timeframe for implementation
- Describe actors and partners
  - Include what level(s) of government would implement and specifically who would be responsible for implementing
  - State government
- Offer considerations or actions to ensure equitable implementation and outcomes
- Describe equity considerations
- Discuss phasing
- Note challenges and opportunities to implementation
  - Describe possible challenges to implementing the strategy, e.g., political will, economic challenges, behavior change
  - Describe possible solutions to overcome challenges
  - Describe any opportunities and how to best take advantage of them
- Note any enabling technologies

Waste

- Define the sector and its scope
- Describe the context of the sector in Pennsylvania
- Introductory paragraph explaining this section will outline recommended strategies to reduce GHG emissions
- Summary of quantitative metrics for sector and by strategy: energy, GHG reduction potential, air quality benefits, health benefits, equity, and economic benefits
- Overview of strategies and overall expected results of implementing them
- Present each strategy separately using the strategy template

Enabling Technologies

The strategies outlined above will rely on existing and future technologies. Leveraging technologies will allow the Commonwealth to more effectively implement the proposed GHG reduction strategies, typically by optimizing performance, reducing overall implementation costs, and/or by reducing GHG emissions at a greater level than possible through alternative technologies or in the absence of technology. Many of these technologies will also be key elements of increasing the resilience and reliability of Pennsylvania's energy systems. Seven key enabling technologies were identified, including:

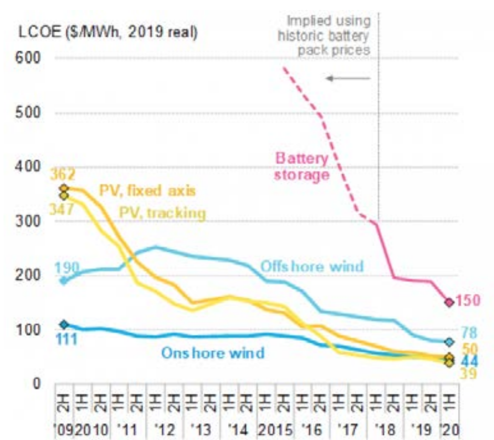
- Incentivizing grid-level battery storage;
- Power-to-gas and blue and green hydrogen;
- Carbon capture, utilization, and sequestration (CCUS);
- Direct Air Capture (DAC);
- Peak energy load and balancing strategies;
- Carbon offsets; and
- Disruptive digital technologies.

A description of each is provided below, as well as short explanation of how the technology is relevant to Pennsylvania in particular.

Encourage and incentivize battery storage at the grid level

Battery technology costs have dropped significantly in recent years, and battery energy storage systems will continue to gain traction as new technologies facilitate aggregation and grid optimization in wholesale markets. Batteries can be paired with other forms of renewable energy, including solar, wind and other variable energy resources as well with as electric vehicle deployments, to enhance the value of specific projects. They can also serve as standalone projects in the grid to provide added peak capacity to areas, and can potentially serve as an alternative to new or upgraded transmission lines.

Figure 17 Global Levelized Cost of Energy (LCOE) of battery storage technology relative to renewable energy generation technologies.



Grid-scale storage is still relatively new in the U.S. In addition to providing capacity to the grid, it also serves a role in smaller grid services such as frequency regulation. Costs for battery storage have dropped in recent years and are expected to continue to drop an additional 40-80% by 2050.[13] See Figure 17 for recent

[13] Cole, Wesley, and A. Will Frazier. 2020. "Cost Projections for Utility-Scale Battery Storage: 2020 Update." Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-75385. https://www.nrel.gov/docs/fy20osti/75385.pdf.

battery price information.[14] Lithium-ion technologies are the leading energy storage solutions; however, several other technologies are under investigation for grid-scale applications including lead-acid, redox flow, and molten salt.[15] While battery storage is currently the leading technology, fly wheels and fuel cell storage using hydrolysis are emerging technologies that have the ability to offer similar storage services to the grid.

Why it matters for Pennsylvania: Pennsylvania's electricity markets are operated by PJM, the independent service operator for the Mid-Atlantic region, and PJM's market rules govern capacity and frequency regulation markets. As the Pennsylvania grid mix continues to change, battery storage will play an important role in providing capacity for peak load days. Even without the addition of solar and wind, battery storage can be used to meet 6-8% of PJM's Annual Peak.[16] With large additions of solar and wind electricity generation sources, a larger percentage can be anticipated. This enabling technology can be paired with the AEPS.

Some states, such as California, Virginia, and Massachusetts, have gone a step further and promoted battery storage technologies through direct incentives or portfolio standard type policies. These policies have been set to require a certain capacity of storage by a target year and are often passed in combination with renewable energy targets and portfolio standards. As Pennsylvania's AEPS is set to plateau in 2021, battery storage policy solutions may be helpful to explore as a way of reducing costs and carbon emissions in the state.

Analyze the potential role of power-to-gas (P2G) and blue and green hydrogen across sectors in meeting Pennsylvania's goals

Alternatives or supplements to natural gas have the potential to provide lower carbon thermal energy for a variety of different uses. Power-to-gas (P2G), blue hydrogen, and green hydrogen are emerging technologies that are already being used throughout the world and have the potential to continue to grow in the coming decades. Hydrogen when used in a fuel cell emits zero emissions, and when combusted results in NOx emissions. Hydrogen can be produced from a variety of resources, including natural gas and biomass or via electrolysis using electricity.

Types of Hydrogen

Blue Hydrogen is a lower-carbon hydrogen production method because it uses carbon capture and sequestration (CCS) technology to reduce carbon emissions

Green Hydrogen is hydrogen created from renewable energy sources such as solar, wind, hydro power, biomass, biogas, or municipal waste.

Why it matters for Pennsylvania: The boom in natural gas extraction in the past 15 years in Pennsylvania has provided wide access to a low-cost fuel used for electricity generation, industrial uses, and building heat for Pennsylvania businesses and homes. As the Commonwealth looks to a low-carbon emissions future, continued investment in alternative fuels are expected as they are anticipated to grow in their cost effectiveness and

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[14] Energy Storage News. 2020. "BloombergNEF: 'Already cheaper to install new-build battery storage than peaking plants.'" Accessed December 15, 2020. Available at: https://www.energy-storage.news/news/bloombergnef-lcoe-of-battery-storage-has-fallen-faster-than-solar-or-wind-i.

[15] Grid-Scale Battery Storage: Frequently Asked Questions. Accessed December 3, 2020 https://www.nrel.gov/docs/fy19osti/74426.pdf.

[16] Denholm, Paul, Jacob Nunemaker, Pieter Gagnon, and Wesley Cole. 2019. The Potential for Battery Energy Storage to Provide Peaking Capacity in the United States. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-74184. https://www.nrel.gov/docs/fy19osti/74184.pdf.

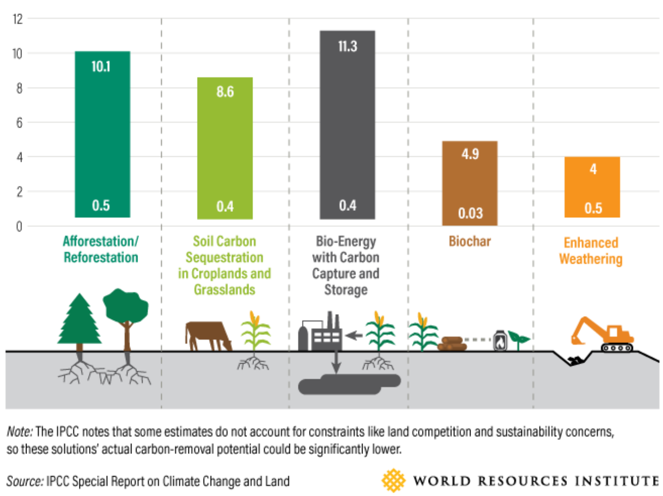
versatility. Both hydrogen and P2G are promising fuels that can be created using electricity, and both fuels have the potential to partially transition from natural gas to lower carbon fuels, thus altering the gaseous fuels marketplace.

The potential to create, store, and distribute hydrogen in Pennsylvania using excess electricity generated from nuclear, in-state solar, and planned offshore wind projects could be a unique and important opportunity. These alternative fuels can be especially effective in difficult to decarbonize industrial sectors that require high temperature processes, such as steel refining or food production, or for use as fuels for a variety of heavy-duty or off-road vehicles.

Analyze the potential role of carbon capture, utilization, and sequestration in meeting Pennsylvania's goals

Carbon capture utilization and sequestration (CCUS) is a broad category of technologies that generally capture CO_2 emissions from fossil fuel combustion source points (e.g., coal-fired power plants, industrial flue stacks) to prevent CO_2 from entering the atmosphere. Capturing emissions at source points is the most efficient means of capture as that is where there is the greatest concentration of CO_2—more than 90% of emissions can be captured this way.[17] There are a variety of technologies for capturing CO_2, including absorption, adsorption, membranes, and others. Once captured, CO_2 is typically transported via pipeline to be permanently sequestered in geologic rock formations or reused in industrial processes and products such as enhanced oil recovery (EOR). Federal incentives such as the 45Q tax credit are making CCUS technologies more financially feasible, spurring commercial growth in the sector. While the technology is effective and proven, there are not many commercial-scale CCUS projects. However, as the technology continues to develop, costs decline, and demand grows, CCUS is poised to grow significantly over the coming years. While CCUS can play a significant role in reducing CO_2 emissions, it is not a substitute for reducing emissions; rather, it is a complementary solution.

Figure 18. IPCC's Estimate Potential of Various Carbon Removal Approaches (gigatonnes of CO2e/year of carbon removal by 2050. Source: WRI.



In addition to manmade technologies, CO_2 can also be captured and stored through natural land-based carbon removal approaches that capture CO_2 in soils, biomass, and oceans. Soils, biomass, and oceans are known as carbon sinks because they extract CO_2 from the atmosphere rather than emit it. There are several strategies to increase the sequestration of CO_2 by these sinks, including reforestation and afforestation, enhanced soil carbon uptake, biochar, enhanced weathering, and bioenergy with carbon capture and storage

[17] C2ES. N.d. "Carbon Capture." Accessed December 3, 2020. Available at: https://www.c2es.org/content/carbon-capture/.

(BECCS). The IPCC released its *Climate Change and Land* special report in 2019 that analyzed the sequestration potential of these strategies, the results of which are shown in Figure 18. Afforestation/reforestation and BECCS were found to have the greatest potential, though BECCS is still very much in the early stages of development. Land-based sequestration strategies mush be balanced with competing land and resource uses.

Why it matters for Pennsylvania: The Commonwealth has a potential sequestration capacity of 88.5 gigatons, enough to store hundreds of years of CO_2 emissions, primarily due to the deep saline formations underground.[18] Additionally, as a major oil and gas producer, it has vast potential to use CCUS technologies for EOR, and in October 2020, Pennsylvania joined a multi-state commitment to establish a regional CO_2 transport infrastructure, signaling its intent to commit to scaling up CCUS.[19] Together, these factors indicate that the Commonwealth is well-placed to implement CCUS technologies that can offer significant economic and climate benefits. Furthermore, Pennsylvania electricity generators, fossil fuel producers and processors, and high-emitting industries could incorporate CCUS technology as a solution for achieving statewide GHG emission reduction goals while preserving a viable fossil fuel-based energy industry. CCUS is expected to play a critical role in achieving GHG reduction goals, but to date, CCUS technologies have had low market penetration due to high costs, lack of policy support, and perceived risks. In 2019, the Commonwealth launched a CCUS Inter-Agency Work Group to identify collaborative opportunities to expedite CCUS in Pennsylvania.[20]

Pennsylvania's large land area offers significant potential for land-based sequestration solutions, but must be balanced with competing land uses such as agriculture, recreation, and urban zones.

Provide resources and education on Direct Air Capture

One solution to climate change is to supplement GHG mitigation efforts by directly removing already existing atmospheric CO_2. Direct Air Capture (DAC) systems capture CO_2 from the ambient air through a variety of different techniques. DAC systems differ from other carbon capture techniques because CO_2 in the atmosphere is only present at low concentrations. DAC systems force air through a highly volatile chemical solution or filter that removes the CO_2 from the air. The resulting capture solution or sorbent is processed to isolate the CO_2 and then reestablished through a variety of different chemical and energy intensive processes. Captured CO_2 can be either permanently sequestered or utilized for products such as carbonated beverages or biofuels. Recent estimates indicate the current technology costs range from $300–

[18] C2ES. 2020. "Carbon capture offers dual economic and climate opportunities in Pennsylvania." Accessed December 3, 2020. Available at: https://www.c2es.org/2020/06/carbon-capture-offers-dual-economic-and-climate-opportunities-in-pennsylvania/.

[19] Pennsylvania Department of Community and Economic Development (DCED). 2020. "Pennsylvania Joins 6 States in Commitment to Plan for CO2 Transport Infrastructure." Accessed December 3, 2020. Available at: https://dced.pa.gov/newsroom/pennsylvania-joins-6-states-in-commitment-to-plan-for-co2-transport-infrastructure/.

[20] Pennsylvania Geological Survey. 2020. "Supporting Responsible Natural Resource Management, CO_2 Transport Infrastructure, and Economic Development in Pennsylvania." Presented by Kristin Carter. Available at: http://files.dep.state.pa.us/Energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/Climate%20Change%20Advisory%20Committee/2020/12-22-20/DEP_CCAC_CCUS_Carter_12-22-2020.pdf.

600/tCO_2.[21] DAC is considered to be among the most expensive carbon capture technologies, and can be as much as three times more expensive than carbon capture at point sources.

Though some forms of DAC can be traced back to the 1930s, the technology has not yet reached commercial scale due to several factors, but primarily due to high energy demand and high production and operating costs. (There are a few existing pilot projects that claim to achieve commercial scale, though there is not a clear definition of what constitutes commercial scale for DAC.[22]) However, over the last 10 years, several businesses and research institutions have made significant advances to reduce the costs and improve the efficiency of DAC technologies. DAC has increasingly gained attention as a tool against climate change as it is becoming clearer that to meet midcentury emissions and global warming goals, the world will likely have to remove existing atmospheric CO_2 in addition to mitigating future emissions. As technology advances, costs fall, and the demand to capture CO_2 increases, DAC is likely to play a larger role in the coming decades. Providing current resources and education to energy providers and regulators, local businesses, academic and research institutions, and other interested stakeholders may better enable the adoption of DAC technology.

Why it matters for Pennsylvania: Some emissions sources like transportation and cement production are especially hard to decarbonize and will continue to create significant emissions, potentially for decades. DAC systems can be installed in the Commonwealth to help offset the emissions from those sources until they are decarbonized. DAC can also be integrated into the Commonwealth's larger CCUS strategy and infrastructure, notably the recent multi-state CO_2 transportation project. DAC requires significant energy inputs, though as a major energy producer, this may not prevent the Commonwealth from adopting DAC technology.

Implement peak load and balancing strategies

Peak load management is a series of technologies and markets that are implemented to reduce strain on the electricity grid. Electricity is a very versatile fuel; however, it needs to be used exactly as it is generated. Flexible grids and load management techniques such as demand response and peak load management programs help solve this challenge as they are capable of reducing electricity use, reducing the potential for grid disruption events or high electricity usage peaks by changing energy loads. Managing peak loads and balancing the grids reduces costs for customers by allowing the system to be more efficient. In the future, managing peak loads may play a bigger role as more renewable electricity comes online and provides variable resources. Distributed Energy Resources and small-scale battery storage projects may also play a role in balancing the grid by generating or discharging electricity to the grid. FERC recently allowed distributed energy resources to participate in wholesale markets as aggregated sources and contribute to load management and grid balancing.

Presently, grid interruptions occur when sudden power plant shutdowns or large transmission line outages occur; however, larger load management issues may occur in the future. Load management technologies and markets can help mitigate these challenges. Time of use rates provide economic incentives to electricity customers to use electricity in ways that match grid

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[21] Innovation for Cool Earth Forum (ICEF). (2018). *Direct Air Capture of Carbon Dioxide.* Available at: https://www.globalccsinstitute.com/wp-content/uploads/2020/06/JF_ICEF_DAC_Roadmap-20181207-1.pdf.

[22] Julio Friedmann. N.d. "Senate Environment & Public Works Committee: The USE IT Act and CCUS Deployment." Written testimony. Available at: https://www.globalccsinstitute.com/wp-content/uploads/2020/06/JF_Senate_EPW_USE-ITAct-CCUSDeployment-2018-1.pdf.

availability. Dual fuel heat pumps use natural gas to support electricity heat pumps and reduce electricity peaks that could occur in winter months.

Beyond technology, load management programs may also increase the flexibility of grid systems. Load management systems provide incentives for building operators and occupants to reduce their usage at key times through advanced HVAC systems or plug load management. Increased EV deployment allows for vehicle batteries to play a role in grid balancing by charging during off-peak times, and one day may potentially provide services to the grid through a vehicle-to-grid integration (VGI) during critical events.[23]

Why it matters for Pennsylvania: Many Pennsylvania businesses already participate in peak load and balancing strategies through either PJM markets or their local utility. These programs reduce overall costs to operate the grid and can provide revenue to participants. As Pennsylvania's electricity grid changes and a higher penetration of variable sources like wind and solar are incorporated, load management of grid peaks will become increasingly important to provide a resilient energy system. As load management programs grow in sophistication, regulators and legislators may also need to address rate structures to ensure that load balancing does not hurt small businesses and low-income residents.

Analyze the potential role of carbon offsets in meeting Pennsylvania's goals

Carbon offsets comprise a range of emission reduction measures not directly covered in a defined emission reduction policy framework, but that can be used to "offset" emissions that are deemed difficult and or costly to reduce under the policy scheme. Offsets are typically allowed to participate in defined policy frameworks in the form of certificates that represents a one-tonne CO_2 or equivalent reduction. Offsets are most commonly administrated through voluntary projects designed specifically for the purpose of reducing GHG emissions. To be deemed sufficiently robust, a carbon offset typically must be shown to be additional to any reduction in emissions that would have been achieved without regulatory compliance or participation in a mandatory scheme, and a project must pass strict verification to be officially certified as genuine. The system can be thought of in an accounting framework in which an organization emits carbon through its actions that results in a "carbon credit," which it balances out by purchasing a carbon offset, or "carbon debit." Offset programs are used for both compliance (run by governmental bodies) and voluntary carbon offsets (typically run by non-governmental organizations (NGOs)).

Offsets are provided by a program or an entity that takes some action—often planting trees, installing renewable energy infrastructure, or similar emissions reduction actions—that will mitigate or sequester CO_2 (or other GHG) emissions. An organization often pursues carbon offsets when the cost of the offset is cheaper than directly reducing its own carbon footprint. Individuals can also purchase offsets. For example, many people purchase carbon offsets to offset their emissions that result from plane travel. Offset prices range from less than \$1/MTCO$_2$e up to \$35/MTCO$_2$e, though prices vary by project type and offset program and few offsets exceed \$15/MTCO$_2$e.[24] There are several critical requirements that carbon offsets must meet:

[23] Two examples of pilots in the U.S. by Fermata Energy include: Vehicle-to-building Pilot Installed by Fermata Energy at North Boulder Recreation Center — Fermata Energy, and Vehicle-to-Building (V2B) Technology Coming to Downtown Denver — Fermata Energy.

[24] Stockholm Environment Institute and Greenhouse Gas Management Institute (SEI and GHGMI). N.d. Available at: https://www.offsetguide.org/understanding-carbon-offsets/other-instruments-for-claiming-emission-reductions/renewable-energy/1387-2/.

1. Verified as legitimate (i.e., a trusted third-party verifies the offset action will truly reduce emissions),
2. Be "additional" (i.e., the activity would not have been taken without the purchase of the offset), and
3. Be real and permanent[25] (i.e., an acre of trees was actually planted and will not be cut down right after the offset is issued).

Carbon offsets have long been criticized for not fully meeting these criteria, and their long-term efficacy remains unconfirmed. Further criticisms point to concerns about equity and that emissions are not prevented.

Why it matters for Pennsylvania: There are two different carbon offset markets that are applicable to Pennsylvania: the formal carbon offset market under RGGI, and the smaller, voluntary market. As RGGI evolves and grows, the carbon offset market will likely expand in kind, and as a RGGI member, the Commonwealth could benefit by either buying or selling offsets, depending on which is more beneficial. As a state with a relatively large population and land area and large forested areas, Pennsylvania is better positioned to provide carbon offsets than many of its neighbors.

Provide resources and education on disruptive digital technologies

Digital technologies, enabled through the Internet of Things (IoT) and high-speed networks such as 5G (fifth generation cellular technology standards), are disrupting traditional business models and standard industry processes. IoT allows everyday objects to connect to the internet and transmit data (e.g., smart thermostats); widespread application of IoT necessitates a high-speed 5G network to exchange data, implement updates, and track performance, and 5G is currently being rolled out nationwide. Artificial intelligence and advanced algorithms are increasingly built into smart and digital technologies for improved optimization, which is expected to continue to make great strides in the coming years. The potential costs, barriers to implementation, and impacts of digital technologies vary greatly based on the scale and scope of application, yet they will undoubtedly reshape the energy sector over the next decade.

The energy sector has historically been an early adopter of digital solutions and has already seen digital technologies penetrate and disrupt energy system supply and demand, from smart metering to distributed grid optimization. Energy end-use sectors such as transport systems, buildings, and industrial plants have already adopted some disruptive digital technologies, including autonomous cars, smart home systems, and 3-D printing processes. Energy companies and utilities are expected to increasingly invest in disruptive technologies to revolutionize remote automation capabilities, real-time automation, and hazard and maintenance sensing ability. Drivers for technology change include targeted education and key changes in regulations or rules that affect market conditions can also stimulate the installation or economic viability of certain technologies. These technologies have applications in all sectors of the CAP.

Why it matters for Pennsylvania: Disruptive digital technologies have the potential to significantly enhance Pennsylvania's energy sector by improving efficiency and optimization. Integrating 5G and IoT into energy generation and transmission can potentially reduce operation costs and energy bills, lessen negative environmental impacts, and mitigate GHG emissions. Energy demand will also shift due to increased connectivity, and the Commonwealth must improve its capability to respond and adapt to the changing demand.

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[25] Or if not permanent, then vintaged with expiration dates.

4 THE IMPACTS OF CLIMATE CHANGE IN PENNSYLVANIA AND ONGOING ADAPTATION EFFORTS

Summary of Priority Risks and Impacts from IA

As a result of projected climate changes, the Commonwealth will be impacted in a variety of ways. The 2021 IA analyzed the consequences for various sectors in Pennsylvania when impacted by six hazards affected by climate change. Key findings from the assessment are described below.

Risks from Specific Hazards

- Flooding is currently the riskiest hazard, and flood risks are projected to increase. Flooding from heavy rain events affects built infrastructure, human health, and agriculture, with ripple effects throughout the economy.
- Risks from increasing average temperatures and heat waves are expected to become as risky as flooding is today by mid-century.
- Increasing average temperatures could affect nearly every aspect of life in the Commonwealth, including infrastructure design, energy costs, recreational opportunities, agricultural practices, and the natural environment.
- Heat waves will become increasingly common and will create particular health and economic risks for vulnerable populations, including low-income populations, the elderly, pregnant women, people with certain mental illnesses, outdoor workers, and those with cardiovascular conditions. These risks will be particularly acute in areas subject to the urban heat island effect.
- Landslides and sea level rise pose relatively low risks statewide but can cause severe impacts in the locations where they occur. For example, sea level rise in the Delaware estuary could drastically change the makeup of the estuary's ecology and also threaten the built infrastructure near the tidal zone. Landslides can have severe consequences if they cut off critical transportation routes, particularly in rural areas.
- Severe tropical storms, flooding, and landslides already pose risks, and these could become more likely or severe in the future. Pennsylvania has an opportunity to build on its existing hazard mitigation practices for these risks.

Overall Risks

- All hazards—especially heat waves, increasing temperatures, and flooding—could affect public health negatively. For example, higher temperatures mean more days with hazardous heat conditions or reduced air quality, and increased risk of heat-related illness. Flooding increases the risks of direct injury from flood waters and of illness caused by contaminated water.
- Climate change will not affect all Pennsylvanians equally. Some may be more at risk because of their location, income, housing, health, or other factors.

Adaptation Priorities

As Pennsylvania works to reduce its climate risks, it must address these inequitable impacts and ensure that adaptation efforts do not inadvertently exacerbate inequities. Instead, adaptation actions should reduce impacts on vulnerable populations. The 2021 IA identified the following top priorities for adaptation action:

- Reduce extreme heat risks to human health, particularly for vulnerable populations.

- Reduce flood risks to infrastructure and communities.
- Help low-income households cope with an increased energy burden.
- Enhance tropical storm and landslide risk mitigation.
- Support the agriculture, recreation, and tourism sectors, as well as forests, ecosystems, and wildlife in the transition to a warmer climate.

Climate risks and related impacts in Pennsylvania could be severe, potentially causing increased infrastructure disruptions, higher risks to public health, economic impacts, and other changes, unless actions are taken by the Commonwealth to avoid and reduce the consequences of climate change. Taking adaptation action also presents an opportunity for Pennsylvania to strengthen its economy, reduce inequities, and build resilience.

As a result of the 2021 IA, 10 key priority areas were identified for climate adaptation. The key priority areas are presented in Figure 19.

Figure 19. Key priority areas for targeted climate adaptation efforts by hazard.

Increasing Average Temperature	Heat Waves	Flooding	Landslides	Combination
1. Health 2. Forest, ecosystems, and wildlife 3. Recreation and tourism 4. Environmental justice and equity	5. Health 6. Environmental justice and equity	7. Environmental justice and equity 8. Built infrastructure	9. Built infrastructure	10. Agriculture impacts from flooding and increasing average temperatures

Ongoing Adaptation Efforts

- Summarize current adaptation efforts broadly
- Describe specific efforts, by sector or focus area

  Include recently announced plan to address flooding, adaptation effort: https://www.governor.pa.gov/newsroom/gov-wolf-announces-plan-to-address-flooding-caused-by-climate-change/?fbclid=IwAR2ZvTFl1cGBPWlUxsZ3ZPxFT6pYaDd4QaVkt5leVw9QrEI341fAqALyKVA

5 OPPORTUNITIES TO ADAPT TO THE IMPACTS OF CLIMATE CHANGE IN PENNSYLVANIA

- ~15-25 pages long, depending on number of strategies and pathways
- Introductory paragraph describing section
- Reference efforts in the IA

Approach

- For each of the priority adaptation areas, review potential adaptation strategies and assemble those strategies into logical "pathways" that indicate example sequencing of strategies, which ones are prerequisites for others, relative timelines, etc.

Figure 20. Adaptation pathway development approach

- Types of strategies
    - Improve understanding
        - Identify, prioritize, and monitor risks
        - Educate and communicate with stakeholders
    - Reduce existing challenges/stressors related to key hazards and risks
    - Reduce sources of future risk
        - Limit exposure sources
        - Limit sensitivities
        - Boost adaptive capacity

5.1.1 Identification Process of Potential Strategies and Adaptation Pathways

- The strategies presented in this memorandum are based on four main sources, for each of the priority risks identified in the IA:
    - Feedback from the Climate Change Advisory Committee (CCAC)and various Commonwealth agencies
    - A review of the 2018 Climate Action Plan, including addendum letters from the CCAC
    - A review of public survey data from DEP on the 2018 Climate Action Plan
    - ICF's knowledge of relevant and common strategies used across the country

5.1.2 Developing Adaptation Pathways

- For each priority risk, the CAP outlines an "adaptation pathway" to manage that risk over time. Adaptation pathways outline a series of steps, including options and decision points over time. For example, pathways may include a handful of near-term, "no regrets" strategies, and then options for medium- and longer-term strategies and criteria for deciding between options in the future.
- Each pathway consists of several adaptation strategies, organized by timeline and tipping points that would prompt implementation of the strategy.

- Emphasize pathways in a descriptive graphic that shows monitoring of tipping points and the anticipated responses
- Describe how pathways are connected to strategies

5.1.3 Identifying Costs and Benefits

- Present identified costs and benefits
- Explain how they result from the strategies
- Mention economic costs and benefits, but also social, equity, and environmental

The 2021 CAP focuses on improving understanding of the equity impacts of climate change in the Commonwealth. The assessment seeks to answer two key questions:

- What populations may be most vulnerable to climate hazards?
- To what extent are climate changes projected to affect communities that are already overburdened?

> **Key Terms**
>
> **Exposed areas—**Geographic areas projected to be affected by climate change based on climate change projections.
>
> **Vulnerable populations—**Populations more likely to experience adverse impacts from being exposed to climate hazards, such as due to factors including demographics (e.g., race, gender), socio-economic status, and life- or livelihood-sustaining needs (e.g., dependence on electricity for critical medical care).
>
> **EJ areas—**Shorthand for "Environmental Justice census tracts," where 20% or more individuals live in poverty, and/or 30% or more of the population is minority.[26]
>
> **Overburdened populations—**"Minority, low-income, tribal, or indigenous populations or geographic locations ... that potentially experience disproportionate environmental harms and risks."[27] EJ areas are used in this assessment as a proxy for locations where populations are already overburdened by hazards and other structural disadvantages.

5.1.3.1.1 Overburdened Populations

The environmental justice and equity consequence ratings for each hazard are based on the degree to which areas most exposed to climate impacts also have a high percentage of overburdened individuals, based on spatial analysis of overlap between exposed areas and EJ areas at the Census block group level.

EJ areas are used as a proxy for locations where populations are already overburdened by hazards and other structural disadvantages. These areas are commonly used by DEP and other state agencies for similar purposes. This approach is also consistent with the approach used in the North Carolina 2020 Climate Risk Assessment and Resilience Plan and is commonly used in similar analysis to capture potentially underserved populations.[28]

EJ areas cannot capture all characteristics of historically disadvantaged, burdened, or underserved populations (e.g., the areas draw defined lines of EJ locations, are based on percentiles, and are based on thresholds from two indicator variables). Nonetheless, they support an approach to identify where climate change impacts could be falling disproportionately to already-disadvantaged communities.

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[26] Pennsylvania Office of Environmental Justice (OEJ). N.d. "PA Environmental Justice Areas."

[27] EPA. 2020. "EJ 2020 Glossary." https://www.epa.gov/environmentaljustice/ej-2020-glossary.

[28] North Carolina Department of Environmental Quality. 2020. North Carolina Climate Risk Assessment and Resilience Plan. https://files.nc.gov/ncdeq/climate-change/resilience-plan/2020-Climate-Risk-Assessment-and-Resilience-Plan.pdf.

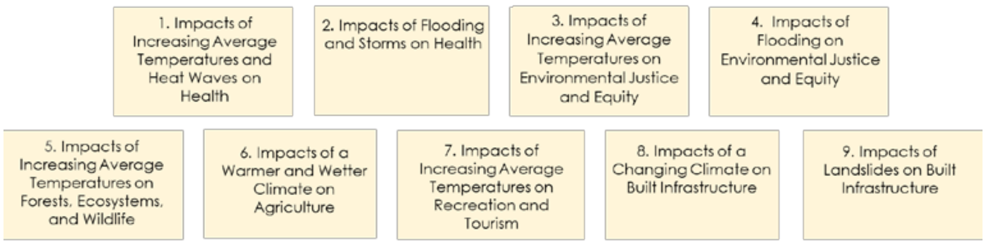
5.1.3.1.2 Vulnerable Populations

The environmental justice and equity consequence sections in this assessment also dive deeper into the nuances of what drives risks of each hazard, identifying specific populations that may be more vulnerable to certain climate changes, and noting where additional factors critical to equity analysis come into play. For example:

- In rural areas where there are several critical roads to support the economy (e.g., for individuals to get to work, or for agricultural centers to receive and send supplies), landslide exposure may be particularly key as consequences of a road being damaged would be severe.
- People who do not speak English may face barriers related to accessing social or health services, making those groups more at-risk to climate hazards such as increased frequency of extreme heat conditions.
- Poverty may reduce a person's capacity to handle significant changes (e.g., temporary loss of work or damage to housing) that may be associated with climate risks.

Adaptation Pathways

- The sections below outline opportunities for Pennsylvania to adapt to the impacts of climate change in each of the designated priority areas (based on the IA).



5.1.4 Addressing the Impacts of Increasing Average Temperatures and Heat Waves on Health

5.1.5 Addressing the Impacts of Flooding and Storms on Health

5.1.6 Addressing the Impacts of Increasing Average Temperatures on Environmental Justice and Equity

5.1.7 Addressing the Impacts of Flooding on Environmental Justice and Equity

5.1.8 Addressing the Impacts of Increasing Average Temperatures on on Forests, Ecosystems, and Wildlife

Impacts in Priority Area

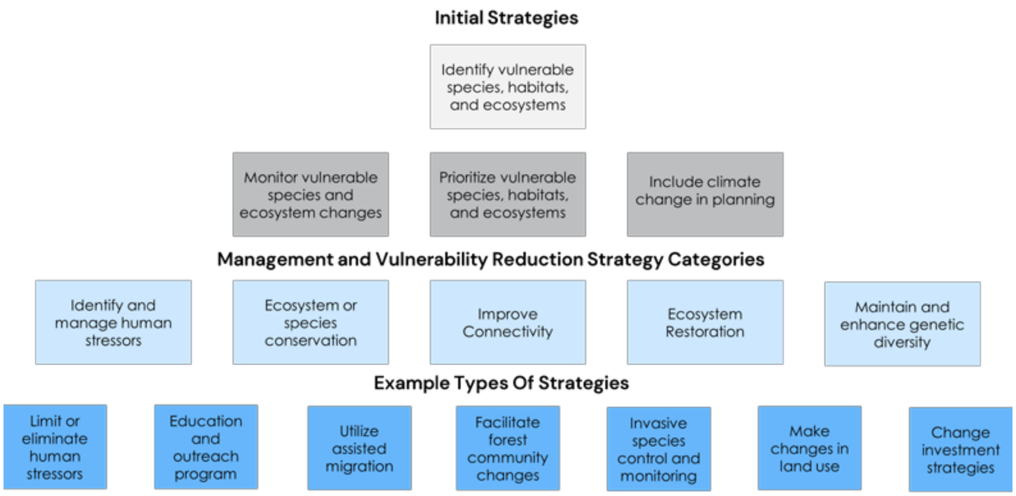
Higher average temperatures are expected to impact forests, ecosystems, and wildlife by altering habitats, changing species' development patterns, and increasing stresses on species and ecosystems. Specific drivers and vulnerabilities identified in the 2021 IA that will particularly harm forests, ecosystems, and wildlife include:

- Decreases in suitable species habitat area;
- Habitat fragmentation;
- Increased prevalence of invasive and pest species;
- Changes in migration, dormancy, leaf development, and blooming cycles;
- Reductions in fish populations, especially in the in Delaware estuary; and
- Increases in algal blooms.

Description of Adaptation Pathway

Various adaptation strategies can be deployed to target these drivers and vulnerability areas. As a first step, the Commonwealth must identify, monitor, and prioritize species and ecosystems to protect and support as temperatures warm. After this evaluation and selection, various strategies can be pursued to manage the impacts of increased average temperatures, reduce stressors on species and ecosystems, and enable species and ecosystems to adapt to the changing climate. Specific strategies fall into broader strategy categories that achieve a generalizable goal. Figure 21 outlines the sequence of strategy categories that can be deployed to manage the impacts of increased average temperatures on the Commonwealth's forests, ecosystems, and wildlife.

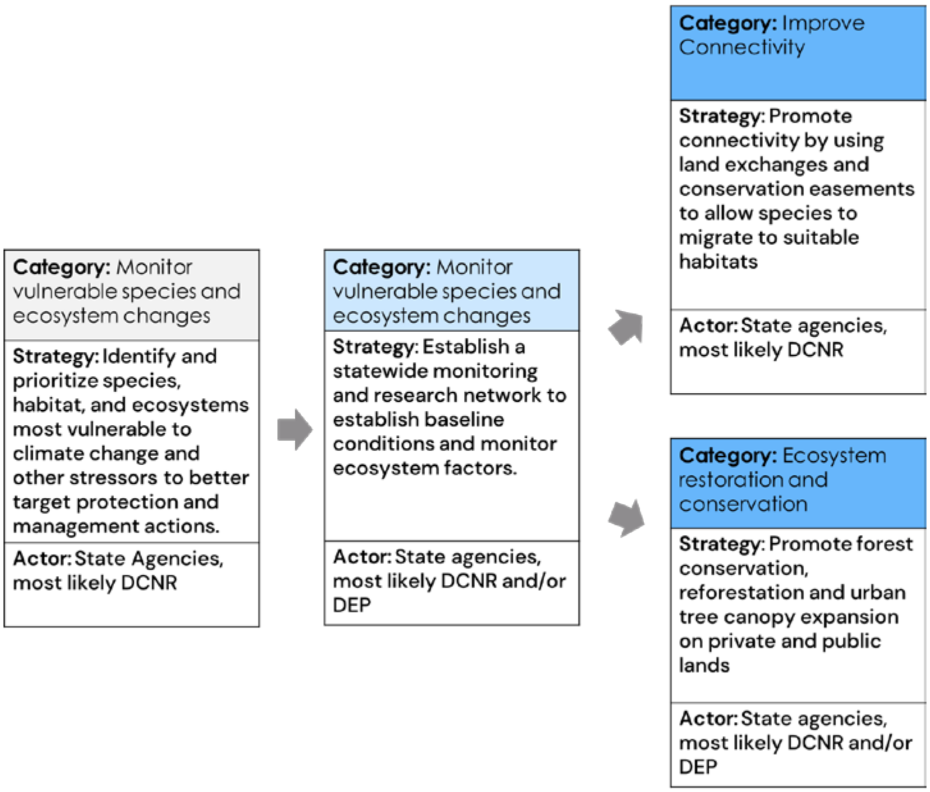
Figure 21. Adaptation strategy category flow diagram for increased average temperatures impact on forests, ecosystems, and wildlife



The sequence of strategies is dependent on state actors' understanding of impacts, the availability of decision support tools, and resource and capacity availability. For example, after identifying and selecting an especially vulnerable forest, DCNR may be able to immediately expand efforts to control pests that may harm critical tree species. However, DCNR may need to wait for increased funding or capacity to work on ecosystem restoration or forest connectivity efforts. As a result, DCNR action might be dependent on state legislature's pursuit of new policies or increasing funding. As action plans are developed, state actors can build action plans from the suite of strategies available. Coordination between the state's leadership is crucial to implementing action plans. Acting according to a shared vision will allow the state legislature, state agencies, and local governments to enable and build upon one another's efforts. Figure 22 outlines a sequence of four strategies led by state agencies that could be pursued to support vulnerable forests in the state.

Appendix XX provides more strategies related to this priority area.

Figure 22. Example set of strategies to be pursued to support forests vulnerable to increased average temperatures



Costs and Benefits

Generally, strategies related to this priority area may significantly range in costs. Low-cost actions may build off existing programs, focus on education and outreach, or managing withdrawals. Higher cost strategies may focus on developing areas for nature preserves or establishing reforestation programs. Overall, strategies in this priority area will promote overall environmental health and may also benefit recreation and tourism. By bolstering ecosystem health and preserving species, more opportunities for engaging in recreation and tourism in the Commonwealth may become available as forests and ecosystems are preserved.

5.1.9 Addressing the Impacts of a Warmer and Wetter Climate on Agriculture

5.1.10 Addressing the Impacts of Increasing Average Temperatures on Recreation and Tourism

5.1.11 Addressing the Impacts of a Changing Climate on Built Infrastructure

5.1.12 Addressing the Impacts of Landslides on Built Infrastructure

6 IMPLEMENTING CLIMATE ACTION IN PENNSYLVANIA

- ~15 pages long
- Introductory paragraph describing section

Challenges and Opportunities

- Pull from challenges identified in GHG strategy reduction section to identify key challenges
- Explain possible solutions to overcome challenges
- Explain possible opportunities and how they could prove fruitful
- Discuss potential methods to take advantage of opportunities
- Talk about potential uses of RGGI revenues (generally) or potential stimulus revenues

Implementation Principles

- Describe best practices to implement strategies
- Strategy implementation will align with the Guiding Principles and Best Practices for EPO Planning and Programming:[29]
    - Enhance collaboration between government and stakeholders.
    - Consider the needs of vulnerable communities and the effects of actions on equity, access, and inclusion.
    - Enhance the marketing of programs and communication of results.
    - Conduct program impact assessments.
    - Create a program tracker.
    - Integrate energy assurance and resilience in planning efforts.
- Touch on institutional arrangements that exist and could be leveraged, identify any gaps in arrangements
- Discuss monitoring and tracking considerations

Equitable and Beneficial Implementation

- Explain how implementation should be designed to ensure the outcomes and benefits are equitable and improve the lives of all Pennsylvanians
- Talk about potential uses of RGGI revenues (generally) or potential stimulus revenues

6.1.1 Creating jobs and economic opportunity

- Explain how implementing the identified strategies will create jobs and economic opportunities
- Describe how proper implementation can maximize the amount of jobs and economic benefits
- Integrate findings from recent clean energy jobs report: https://stateimpact.npr.org/pennsylvania/2021/01/29/report-pennsylvania-stands-to-gain-243000-jobs-a-year-from-clean-energy-investment/

[29] DEP. 2020. Clean Energy Program Plan. Available at: http://www.depgreenport.state.pa.us/elibrary/GetDocument?docId=3412364&DocName=CLEAN%20ENERGY%20PROGRAM%20PLAN.PDF%20%20%3cspan%20style%3D%22color:green%3b%22%3e%3c/span%3e%20%3cspan%20style%3D%22color:blue%3b%22%3e%28NEW%29%3c/span%3e#.

6.1.2 Addressing health

- Explain how human health is influenced by the local climate and how the climate adaptation strategies and GHG reduction strategies will improve human health

6.1.3 Addressing equity barriers

- Explain what equity barriers exist and potential solutions to overcome barriers.

Key Steps and Stakeholders for Implementation

- Describe high-level steps and stakeholders that are most critical for implementing adaptation and GHG reduction strategies
- Add a timeline graphic showing phasing of GHG reduction strategies
- Add a timeline graphic showing phasing of adaptation strategies
- Indicate potential or actual roles of stakeholders to implement the CAP

APPENDIX A – KEY TERMS

- Glossary
- Acronyms

APPENDIX B – METHODOLOGY DETAILS

BAU Methodology

The BAU was developed through a series of steps that mostly align with the BAU approach ICF used for the 2018 Pennsylvania CAP update and the Energy Assessment Report. The exceptions to this methodology and data sources are noted below. The primary methodological steps undertaken were as follows:

1. Compiled and integrated historical energy and emissions data, primarily from the Energy Information Administration (EIA) State Energy Data System (SEDS), the Environmental Protection Agency State Inventory Tool (SIT), and state-specific data sources. Section 2.2.1 provides an overview of these data sources in more detail.
2. Projected future activity primarily using the EIA Annual Energy Outlook (AEO) Reference Case and made adjustments to align AEO and SEDS geographies. While SEDS data are provided at the state level, AEO data are forecasted at the regional level. To account for this geographical discrepancy, DEP and ICF applied the AEO regional growth rate for a particular energy resource to the historical SEDS data to project Pennsylvania Commonwealth-level energy resource data. Other projection methods, such as those based on state-specific regulations on oil and gas methane emission controls and HFC phaseouts, were incorporated as described below.
3. Adjusted historical and future activity data to ensure consistency, to capture available Pennsylvania-specific data, to address existing data gaps, and to incorporate the analysis team's expert input using resources such as ICF's Integrated Planning Model (IPM).
4. Applied emission factors when available to estimate GHG and criteria air pollutant emissions.

GHG Accounting Methods

The BAU assessment followed the GHG accounting methods used for the existing state GHG inventory. Notably, the BAU estimates and incorporates emissions from electricity generation in total emissions estimates for the Commonwealth. Emissions from electricity consumption (e.g., from the residential and commercial sectors) are reported for informational purposes. This is consistent with the request from the CCAC, and will make accounting for policies such as RGGI more transparent and consistent. It will also allow for consistent future goal tracking using the SIT. Data for the SIT and other resources were adjusted and aligned with state-specific data, where available and feasible.

Base and Projection Years

The BAU scenario incorporated activity and emissions data through 2050. DEP and ICF modeled the BAU starting in 2005, as this is the baseline year for Pennsylvania's 2050 GHG reduction goal. Historical data for 2000 – 2005 are also shown to provide a consistent timeseries. The last year for which SIT data were available is 2017. Projections that relied on SIT data were developed annually, starting in 2018, for each year through 2050. Emission categories that used other datasets, such as the AEO, were projected beginning in the most recent year of available data (in most cases this was 2019).

Policy Assumptions

The BAU scenario projects what emissions in Pennsylvania would be through 2050 if only the existing (as of December 2020) GHG reduction policies and programs continue. This includes policies that are in place today, or are well underway in the proposal process. Many of these policies have targets that come prior to 2050 (e.g., AEPS in 2022 and RGGI in 2030). For these policies, the BAU relies on the assumption that these targets stay constant through 2050 (e.g., the 2030 RGGI cap is the same cap applied in the modeling in 2050).

The policies included in the BAU are:

- **Act 129** – Act 129 requires PA's seven largest electric distribution companies (EDCs) to reduce energy use within their service territory.
- **Alternative Energy Portfolio Standard (AEPS)** – AEPS sets targets for the amount of electricity supplied by PA's EDCs that must come from renewable sources.
- **Regional Greenhouse Gas Initiative (RGGI)** – By joining RGGI, Pennsylvania is obligated to reduce their GHG emissions in coordination with other member states.
- **HFC Phaseout** – PA will phase out HFCs in accordance with EO 2019-01 and the AIM Act.
- Policies included in the AEO Reference Case, as identified in https://www.eia.gov/outlooks/aeo/assumptions/pdf/summary.pdf.

Sector Approach and Data Sources

The following sections outline the approaches and accompanying data sources used in to develop historic BAU estimates and projections.

Transportation

DEP and ICF used transportation fuel use data from SEDS and emission factors from the SIT to analyze historical transportation emissions. Transportation fuel use growth rates from AEO were used to project fuel use and then emissions (applying appropriate emission factors) through 2050. This data was supplemented with state-specific data and assumptions for required production and use levels for biodiesel. Emissions associated with electricity use were not included in total emissions but reported separately for informational purposes.

Residential and Commercial Buildings

Historical building energy consumption data were pulled from SEDS, along with emission factors from the SIT, to calculate past GHG emissions. The analysis team used AEO data and trends, along with historical data, to project residential and commercial building energy use through 2050. Emissions associated with electricity use were not included in total emissions but reported separately for informational purposes.

Industrial

Similar to the residential and commercial sectors, industrial sector energy use and emissions were taken from SEDS and the SIT. To project activity and emissions, AEO growth trends and related emission factors were applied. Emissions associated with electricity use were not included in total emissions but reported separately for informational purposes.

HFC emissions were extrapolated based on the HFC phaseout regulations that requires GHG emissions reductions of 26% below 2005 levels by 2025 and 80% below 2005 levels by 2050. These targets align with the statewide emission reduction goals established by Governor Tom Wolf in EO 2019-01.

Fugitive Emissions from Energy Production Oil and Gas Systems

Fugitive GHG emissions estimates from oil and natural gas production were based on estimates from the SIT, which uses production data from EIA and the Office of Pipeline Safety (OPS). The historical emissions data from SIT were then projected to 2050 using natural gas and crude oil production and consumption estimates from AEO (Reference Case). Production estimates were used to project natural gas and oil production, while consumption estimates were used for transmission and distribution. The BAU scenario does not account for any reductions from a proposed DEP rule that would reduce the amount of methane emitted through control measures aimed at limiting emissions from volatile organic compounds (VOCs).[30] These reductions are captured in the associated strategy, Reduce Methane Emissions Across Oil and Natural Gas Systems. Fugitive emissions from coal mines were also based on estimates from SIT, which use a combination of EPA data (primarily from the U.S. GHG Inventory) and EIA.

Renewable and Alternative Energy (Non-Electricity)

Biogas (including agricultural waste, wastewater, and landfill gas) estimates are only available for the industrial sector in the EIA data sources. DEP and ICF therefore relied on biogas supply/consumption information from a mix of sources, including EPA's Landfill Methane Outreach Program (LMOP) and AgSTAR project databases, a listing of wastewater sites in Pennsylvania,[31] and a database of CHP projects maintained by ICF. This information is readily available and was compiled by ICF through its work with the American Gas Foundation to assess renewable gas supply in the United States. Projections for these sources were based on outputs from the IPM.

Electricity Generation

Historical electricity generation was pulled from SEDS, along with emission factors. Future annual electricity load projections (aggregated for all sectors) were then fed into IPM, which projected future generation mixes and emissions through 2050. The analysis team worked to align historical SEDS data and future IPM projections to ensure consistency. The emission caps from RGGI will continue to decrease through 2030; our model currently holds the 2030 cap in place for the remainder of the time series.

Waste and Wastewater

Both waste and wastewater emissions reflect non-energy sources in the BAU, as the SIT does not allocate emissions from electricity consumption in these sectors. The BAU model does not include CO_2 from landfills in waste emissions estimates, as this is considered biogenic.

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[30] This rulemaking establishes requirements for storage vessels, natural gas driven pneumatic controllers, natural gas-driven diaphragm pumps, reciprocating and centrifugal compressors, and fugitive emissions components. For more information see: https://www.dep.pa.gov/Business/Air/pages/methane-reduction-strategy.aspx

[31] See: http://www.resourcerecoverydata.org/biogasdata.php.

For wastewater, similar to waste, the BAU model does not include biogenic CO_2 from treatment plants. The BAU projects wastewater emissions from increased flows due to population growth and landfill waste emissions from the historic activity data and projected waste disposal totals.

Agriculture

Agriculture emissions were estimated using the SIT Agriculture module. Projections for the agricultural sector include CH_4, N_2O, and CO_2 emissions using data from the SIT.

LULUCF

ICF estimated net carbon sequestration/emissions from LULUCF using data from the SIT, this is based on data from the US Forest Service. Projections for LULUCF were held constant to latest year of available data for the BAU. Additional changes on forest cover and natural sequestration may be addressed through the GHG reduction analysis.

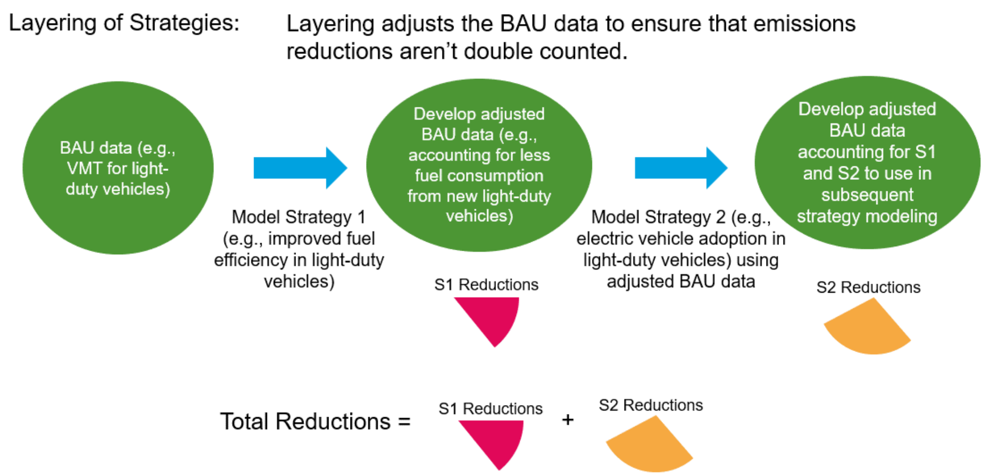
GHG Reduction Strategy Methodology

The GHG accounting approach used in modeling GHG reductions for this plan is aligned with the GHG accounting approach used in the GHG inventory and BAU projections, and accounts for the interactions between various strategies to ensure accurate accounting. The analysis team used methods and tools similar to what were used to conduct the 2018 CAP analysis with a few exceptions. The analysis was primarily conducted using Excel-based tools, the exception being the use of the IPM model for the electricity sector analysis. ICF also made a few changes to the GHG accounting approach, including accounting for electricity sector generation emissions (pulling out any electricity-related emissions from end use sectors) and applying marginal emission factors (i.e., using emission factors more specific to the fuel/technology to better characterize the change of emissions) where appropriate to estimate reductions. As part of the GHG reduction analysis, where feasible, ICF also estimated changes in air quality emissions (e.g., NO_x and SO_x) at the state level. Key aspects of this accounting approach include:

- Reductions in GHG emissions as a result of reductions in direct fuel use for all energy other than electricity is represented in the end use sector (i.e., residential, commercial, industrial, and transportation).
    - Note: Reductions in GHG emissions as a result of changes in end use electricity consumption are not included in totals to avoiding overlapping GHG reductions from different sectors and actions (i.e., "double counting"). This information is reported informally and uses a marginal emission factor for energy efficiency and distributed energy (i.e., CHP) informationally reported reductions from electricity use changes. See also below on GHG emissions for electricity generation.
- Reductions in GHG emissions as a result of changes in both electricity consumptions and the generation mix are accounted for in the electricity generation sectors. GHG emissions from electricity generations are modeled in a two-step process:
    - Estimate changes in electric load as a result of all strategies that impacts load (e.g., energy efficiency, electrification).
    - Feed the load changes over time into the Integrated Planning Model© with policy assumptions to estimate generation mixes over time.
- Layering the impacts of certain strategies to avoid over-estimating reductions, as outlined in Figure 23. Layering the impacts of strategies indicates the assumed order of implementation in which strategies occur to account for the interactions between them (e.g., a strategy that targets improving fuel efficiency standards may reduce overall fuel consumption, and a

second strategy that targets electric vehicle adoption should incorporate the impacts of more fuel-efficient vehicles on the road at the outset to appropriately assess the impact on GHG emissions).

Figure 23. Approach to Layering Strategies



Buildings Sector

Support Energy Efficiency Through Building Codes

Description

This strategy includes adopting the most current building codes, enforcing existing codes, encouraging local adoption of stretch codes, and educating and training code officials and inspectors on code enforcement. To ensure effective compliance with building codes, this strategy also includes steps to educate municipalities on their ability to implement and require codes beyond the State Code, including "stretch codes" such as International Green Construction Code (IgCC), Zero Code and NetZero Codes.

Method, Data and Key Assumptions

- **Residential Energy Savings:** Using ICF's Energy Code Calculator,[32] the analysis team assumed an International Energy Conservation Code (IECC) 2015 base code and then implemented projected future IECC code versions every six years through 2050. The analysis team also reviewed the 2021 IECC code and considered what aspects to integrate in the analysis. This implementation timeframe was based on the actual time it took to adopt the 2015 codes in Pennsylvania.[33] The team assumed 90% code compliance for all new construction homes with a 30-year measure life, based on requirements set in 2009 SEP grants.[34] New home projections were provided by Pacific Northwest National Laboratory.[35] This approach delivers both electricity and natural gas savings.
- **Commercial Energy Savings:** Again, using ICF's Code Calculator, the team assumed an American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 2007 base code and implement projected future ASHRAE code versions every six years through 2050. The team assumes 90% code compliance for all new construction, renovations, and additions with a 30-year measure life. New commercial square foot projections were provided by Pacific Northwest National Laboratory. This approach delivers both electricity and natural gas savings.
- **Strategy Layering:** This strategy was applied prior to any other building energy strategy.
- **Emissions Accounting:** Emissions savings as a result of building electrification appear in two places—emissions related to electricity consumption are accounted for in the electricity generation sector and emissions related to displaced gas or fossil use appear in the buildings sector. Emissions from electricity consumed by residential and commercial buildings are reported for informational purposes only and are not included in emissions totals. These

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[32] The Energy Codes calculator is a proprietary tool that estimates changes in energy use based on assumed updates to building codes for new construction.

[33] In May 2018 Pennsylvania moved ahead with adopting the 2015 model International Energy Conservation Code commercial and residential energy codes, while incorporating some select improvements from the 2018 model code. These changes will go into effect in October of 2018. https://www.dli.pa.gov/ucc/Documents/rac/UCC-RAC2015-Code-Review-Report.pdf.

[34] During the 2009-12 Recovery act period, SEP grants came with a condition that all states set plans to achieve 90% code compliance. A DOE field study for PA shows close to 90% compliance: https://www.energycodes.gov/sites/default/files/documents/Pennsylvania_Residential_Field_Study.pdf.

[35] 19 Pacific Northwest National Laboratory. (PNNL). 2014. Utility Savings Estimator. Accessed on July 13, 2018. Available at https://www.energycodes.gov/resource-center/utility-savings-estimator.

informational emission reductions were calculated using marginal emission factors for the grid over time.

Applicable Emission Factors

- **GHG:** GHG emission factors for electricity come from IPM. ICF calculated a blended gas supply emission factor over time based on the available supply of renewable natural gas (see Fuel Supply 1 measure) and overall gas demand across the state. Other fuel emission factors come from the U.S. Inventory and 2006 IPCC Guidelines for National Greenhouse Gas Inventories (consistent with the State Inventory Tool).
- **Air Quality:** Air Quality emissions factors for electricity come from IPM. Emissions factors for natural gas, coal, fuel oil and other fuels come from EPA AP-42 Fifth Edition Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources; and Emission Factor Supporting Documentation for the Final Mercury and Air Toxics Standards. Mercury Air Toxic Standards (MATS).

Costs and Benefits Analysis

- **Components:** Costs associated with residential and commercial energy efficiency was taken from PNNL's Cost-Effectiveness of ASHRAE Standard 90.1-2013 for the State of Pennsylvania[36] and PNNL's Cost-Effectiveness Analysis of the Residential Provisions ofthe 2015 IECC for Pennsylvania[37]
- **Assumptions and data:** For Residential: The Total Housing Units for the State of Pennsylvania and throughout the US was take from US Census data[38]. Data on Pennsylvania homeownership was taken from St. Louis FED[39]. A value for US home owners reporting retrofit projects was taken from Harvard's work on Improving America's Homes[40]. A value for the total retrofits in Pennsylvania's housing sector was calculated by using a ratio of the total retrofits vs the total us housing stock and multiplying it by Pennsylvania's total housing units. Energy savings from retrofits was taken from PNNL's cost effectiveness studies. A average square footage of PA's homes and cost per square foot of retrofit was taken from PNNL's studies and applied to the portion of PA's total housing units undergoing a retrofit to determine costs.

  For Commercial: BAU growth square footage was applied to a base energy codes and subtracted from an advanced energy code from ICF's energy code tool based on code updates every six years to determine energy savings. PNNL's costs per square foot was applied to determine capital costs.

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[36] Pacific Northwest National Laboratory. (PNNL). 2014 https://www.energycodes.gov/sites/default/files/documents/Cost-effectiveness_of_ASHRAE_Standard_90-1-2013-Pennsylvania.pdf

[37] Pacific Northwest National Laboratory. (PNNL). 2015 https://www.energycodes.gov/sites/default/files/documents/PennsylvaniaResidentialCostEffectiveness_2015.pdf

[38] United States Census https://www.census.gov/data/tables/time-series/demo/popest/2010s-total-housing-units.html

[39] St. Louis FED https://fred.stlouisfed.org/series/PAHOWN

[40] Joint Center for Housing Studies of Harvard University. Improving America's Housing 2019 https://www.jchs.harvard.edu/sites/default/files/Harvard_JCHS_Improving_Americas_Housing_2019.pdf

Improve Residential and Commercial Energy Efficiency (Electricity)

Description

This strategy includes several actions to improve residential and commercial energy efficiency by requiring increased residential and commercial energy efficiency improvements targeted at kWh savings, either within the existing framework of or a modified framework of Act 129 (e.g., increasing savings targets and removing spending caps).

For Act 129, this includes increasing the low- to moderate-income (LMI) share of spending and reforming cost-effectiveness tests to support more LMI focus, and adding climate mitigation and resilience benefits to cost effectiveness tests. To enhance Act 129 effectiveness and increase savings, incentives and education should leverage programs like Low Income Home Energy Assistance Program (LIHEAP) and Weatherization Assistance Program (WAP).

Beyond Act 129, this strategy includes statewide programs targeted at reducing electricity use in large commercial buildings through a gradually expanding Commercial Building Energy Performance Program. Such a program could begin with energy benchmarking of large facilities, and grow to include retro-commissioning or energy efficiency requirements.

Method, Data, and Key Assumptions

- **Residential Electricity Savings:** Based on the Pennsylvania Statewide Evaluator's (SWE) Energy Efficiency Potential Study for Pennsylvania, the analysis team applied the calculated maximum achievable potential energy savings from 2021-2040 (1.5%) and 2041-2050 (2%). Historical evidence suggests this potential estimate can be achieved. The analysis team assumed a measure lifetime of 10 years.
- **Commercial Electricity Savings:** Again, using the SWE's study, the analysis team applied the maximum achievable potential from 2021-2025 (0.8%) followed by 1.0% annual incremental savings for years 2026-2040 and 1.5% for years 2041-2050. The team assumed a measure lifetime of 10 years. For large commercial building over 50,000 square feet, a series of building performance programs will accelerate energy efficiency. The model assumes a benchmarking program is in place from 2021-2026, followed by a building retuning program from 2027-2032, and then a building retro-commissioning or energy efficiency program starting in 2033. Assumed savings from these programs are 7%, 12%, and 25% respectively across all forms of energy. Program savings are modeled based on city-level programs currently being enacted. -
- **Strategy Layering:** SWE's study will serve as the base source for modeling savings in the residential and commercial sector. Accelerated progress for a subset of buildings will be layered on top of the base strategies. This strategy is expected to impact any portion of energy use (representative of buildings) not already impacted by Buildings Strategy #1.
- **Emissions Accounting:** Emissions savings as a result of energy efficiency improvements that affect electricity consumption are accounted for in the electricity generation sector (reduced generation = reduced emissions). Emissions from electricity consumed by residential and commercial buildings are reported for informational purposes only and not included in emissions totals. These informational emission reductions will be calculated using marginal emission factors for the grid over time.

Applicable Emission Factors

- **GHG:** GHG emission factors and emissions come from ICF's Integrated Planning Model (IPM).
- **Air Quality:** Air quality emission factors come from IPM (NO_x and SO_x).

Costs and Benefits Analysis

- **Components:** Costs were derived from previous Pennsylvania Act 129 program costs. Total residential and non-residential costs were taken from the SW EE Potential study and broken out to determine admin costs, participant costs and total incentives based on the total verified impacts. Costs were then allocated to future years based on $/MWh saved from the various sectors. No program or participant costs were estimated for the building performance program.
- **Assumptions and data:** Data from Philadelphia's Benchmarking Program was used to estimate emissions reductions from the initial building performance policy[41].

[41] City of Philadelphia, Philadelphia Building Energy Benchmarking 2019 Report https://www.phila.gov/media/20191210091804/2019-Municipal-Energy-Benchmarking-Report.pdf

Improve Residential and Commercial Energy Efficiency (Gas)

Description

This strategy includes creating a new energy efficiency program focused on reducing gas consumption that is similar to the voluntary gas demand side management (DSM) programs already in place with some Pennsylvania gas utilities. This strategy specifically includes statewide programs targeted at reducing natural gas use in large commercial buildings through a gradually expanding Commercial Building Energy Performance Program. This type of program includes energy benchmarking of large facilities, and grow to include retro-commissioning or energy efficiency requirements. It also includes an allocation of a certain portion of funds for LMI individuals, and reform cost-effectiveness tests, e.g., by adding climate mitigation and resilience benefits to the tests.

Method, Data and Key Assumptions

- **Residential Gas Savings:** Using an American Council for an Energy-Efficient Economy (ACEEE) Energy Efficiency Resource Standard (EERS) policy yes,[42] the analysis team applied the Massachusetts EERS target of 1.1% annual incremental natural gas savings from 2020-2025 followed by 1.5% annual incremental savings from 2026-2050. The team assumed a measure lifetime of 10 years. The analysis team will also review data from the PUC and in rate filings related to voluntary gas programs to determine if adjustments to the assumptions should be made.
- **Commercial Gas Savings:** The analysis team used the same approach used for residential gas savings, with savings percentages mirroring electricity.
- **Strategy Layering:** Accelerated progress for a subset of buildings will be layered on top of the base strategies. This strategy is expected to impact any portion of energy use (representative of buildings) not already impacted by Building Strategy #1.
- **Emissions Accounting:** Emissions savings as a result of energy efficiency improvements that affect energy consumption are accounted for in the buildings sector.

Applicable Emission Factors

- **GHG:** The analysis team calculated a blended gas supply emission factor over time based on the available supply of renewable natural gas (see Fuel Supply 1) and overall gas demand across the state.
- **Air Quality:** Air quality emissions factors for gas combustion are from the EPA AP-42 Fifth Edition Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources; and Emission Factor Supporting Documentation for the Final Mercury and Air Toxics Standards. Mercury Air Toxic Standards (MATS).

Costs and Benefits Analysis

- **Components:** Costs were derived from previous Pennsylvania Act 129 program costs and through a conversion from MWh to BBTU. Total residential and non-residential costs were taken from the SW EE Potential study and broken out to determine admin costs, participant costs and total incentives based on the total verified impacts.
- **Assumptions and data:** Data from Philadelphia's Benchmarking Program was used to estimate emissions reductions from the initial building performance policy

[42] ACEEE. 2020. "Energy Efficiency Resource Standard." Accessed December 15, 2020. Available at: https://www.aceee.org/toolkit/2020/02/energy-efficiency-resource-standard.

Incentivize Building Electrification

Description

This strategy includes incentivizing building electrification (e.g., heating and hot water) for the residential and commercial sectors. It also includes a new program focused on beneficial electrification, possibly modeled on the New York Clean Heat program. This includes incentives for converting fuel oil and natural gas to electricity in existing buildings and electrification of new buildings where there are large natural gas infrastructure costs or where fuel oil is the alternative.

Method, Data and Key Assumptions

- **Method:** The analysis team applied an average annual energy savings potential for residential and commercial buildings to evaluate energy consumption (natural gas, and fuel oil) reductions from electrification of existing buildings. For new buildings, the team evaluated the amount of displaced energy consumption. The team assumed that a set share of residential and commercial buildings will be retrofitted with electric heating and appliances by 2050, and that a set share of new residential and commercial buildings will be all-electric by 2050. Modeled existing and new building electrification shares by 2050 information can be found in the table below.

Sector	*Existing Buildings*	*New Buildings*
Residential Single Family	75%	90%
Residential Multi-Family	60%	80%
Commercial	50%	75%

- **Strategy Layering:** This strategy is applied after Building Strategies #1, 2, and 3.
- **Emissions Accounting:** Emissions savings or increases as a result of building electrification appear in two places—emissions related to kWh are accounted for in the electricity generation sector and emissions related to displaced gas or fossil use appear in the buildings sector. Emissions from electricity consumed by residential and commercial buildings are reported for informational purposes only and not included in emissions totals. These informational emission reductions were calculated using marginal emission factors for the grid over time.

Applicable Emission Factors

- **GHG:** GHG emission factors for electricity come from IPM. The analysis team calculated a blended gas supply emission factor over time based on the available supply of renewable natural gas (see Fuel Supply 1 measure) and overall gas demand across the state. Other fuel emission factors are from the U.S. GHG Inventory and 2006 IPCC Guidelines for National Greenhouse Gas Inventories (consistent with the State Inventory Tool).
- **Air Quality:** Air Quality emissions factors for electricity come from IPM. Emissions factors for natural gas, coal, fuel oil and other fuels are from EPA AP-42 Fifth Edition Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources; and Emission Factor

Supporting Documentation for the Final Mercury and Air Toxics Standards. Mercury Air Toxic Standards (MATS).

Costs and Benefits Analysis

- **Components:** Program costs were derived from previous Pennsylvania Act 129 program costs. Analysis includes costs of the program and energy cost changes (savings from natural gas and fuel oil, increases from electricity)
- **Assumptions and data:** Electrification conversion factors assumed a HSPF (Heating Seasonal Performance Factor) for residential single family and multifamily of 8.2. Electrification of commercial sector included a 18% efficiency electrification factor take from ACEEE's "Electrifying Space Heating in Existing Commercial Buildings" study.[43]

[43] American Council for an Energy Efficiency Economy (ACEEE) 2020. Electrifying Space Heating in Existing Commercial Buildings, ACEEE 2020, p. 56 Available at: https://www.aceee.org/sites/default/files/pdfs/b2004.pdf

Transportation Sector

Increase fuel efficiency of all light duty vehicles and reduce vehicle miles traveled for single occupancy vehicles

Description

This strategy includes a reduction of vehicle miles traveled (VMT) for single-occupancy vehicles by implementing travel demand strategies such as shifting travel time, mode choice, and route, increasing the frequency of telecommuting. It also includes increased fuel efficiency standards. These efforts are paired with land-use and development policies that develop and promote sustainable transportation modes (walking, biking, transit, carpool) in existing densely populated urban areas, followed by expansion to underserved communities outside of urban centers in the medium and long term.

Method, Data and Key Assumptions

- **VMT Reduction:** The analysis team used an overall VMT reduction target of 3.4% by 2030 and 7.5% of total VMT from BAU by 2050. This estimate is based on the draft Pennsylvania Energy Assessment Report prepared in 2018,[44] as well as Pennsylvania-specific runs of the EPA's Motor Vehicle Emission Simulator (MOVES), U.S. Energy Information Administration's (EIA) Annual Energy Outlook 2018, and Federal Highway Administration VMT projections.[45] The analysis team also captured VMT reductions from fuel efficiency improvements. Fuel efficiency improvements included are a 20% improvement for light-duty vehicles between 2026 and 2050 beyond the existing CAFÉ standards in place today.
- **Strategy Layering:** The reductions from this strategy were accounted for before Transportation strategies 2 and 3.
- **Emissions Accounting:** Changes in electricity consumption are accounted for in the electricity generation sector and then reported out for informational purposes here (similar to buildings). Other fuel reduction and related emission reductions are represented in this strategy.

Applicable Emission Factors

- **GHG:** GHG emission factors are from the State Inventory Tool Mobile CO2FFC Module. Electricity emission factors are from ICF's IPM.
- **Air Quality:** Air quality emission factors are ICF-developed factors based on MOVES runs provided by DEP.

Costs and Benefits Analysis

- **Components:** The cost analysis includes savings from reduced fuel consumption and costs of VMT reduction program implementation.
- **Assumptions and data:** Assumed a $0.03/mile cost for program implementation. Fuel costs were taken from AFLEET, AAA, and EIA.

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[44] Pennsylvania Department of Environmental Protection (DEP). 2018. Draft Report: Energy Assessment Report for the Commonwealth of Pennsylvania.

[45] Federal Highway Administration (FHWA). 2018. FHWA Forecasts of Vehicle Miles Traveled (VMT): Spring 2018. Accessed July 3, 2018. Available at: https://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_forecast_sum.pdf.

Implement the Multi-state Medium-and Heavy-duty Zero-emission Vehicle Memorandum of Understanding

Description

This strategy includes the implementation of the multi-state medium- and heavy-duty zero-emission vehicle memorandum of understanding (MHD ZEV MOU), of which the Commonwealth of Pennsylvania is a co-signatory. The MOU has the goal of reaching net zero emissions from MHDVs by 2050. This target would be achieved through a mix of fuel switching to electric and other zero-emission vehicles such as fuel cell electric vehicles (FCEV), and would eliminate vehicles that have a disproportionate impact on air quality due to diesel emissions and/or that have a relatively low fuel economy. Potential actions (as stated in the MOU) may include:

- Financial vehicle and infrastructure incentives.
- Non-financial vehicle and infrastructure incentives.
- Actions to encourage public transit and public fleets to deploy zero emission MHDVs.
- Effective infrastructure deployment strategies.
- Funding sources and innovative financing models to support incentives and other market-enabling programs.
- Leveraging environmental and air quality benefits associated with the adoption of the California Advanced Clean Trucks rule under Section 177 of the Clean Air Act.
- Coordinated outreach and education to public and private MHDV fleet managers.
- Utility actions to promote zero emission MHDVs, such as electric distribution system planning, beneficial rate design and investment in "make-ready" charging infrastructure.
- Measures to foster electric truck use in densely populated areas.
- Addressing vehicle weight restrictions that are barriers to zero emission MHDV deployment.
- Uniform standards and data collection requirements.

Method, Data and Key Assumptions

- **Method:** 30% of medium- and heavy-duty vehicles will be alternative fuel vehicles by 2030, and 100% will be by 2050, aligning with Pennsylvania's commitment in the MHDV MOU. MOVES data was used to determine the breakdown of vehicle type and to calculate displaced fuel consumption due to changes in vehicle type.
- **Strategy Layering:** This measure used Transportation Strategy #1 as a baseline to avoid double-counting emissions reductions.
- **Emissions Accounting:** Changes in electricity consumption are accounted for in the electricity generation sector and then reported out for informational purposes here (similar to the buildings strategies). Other fuel reductions and related emission reductions are represented in this strategy.

Applicable Emission Factors

- **GHG:** GHG emission factors are from the State Inventory Tool Mobile CO2FFC Module. Electricity emission factors come from ICF's IPM.
- **Air Quality:** Air quality emission factors are ICF-developed emission factors based on MOVES runs provided by DEP.

Costs and Benefits Analysis

- **Components:** The analysis includes capital costs of vehicles and charging infrastructure, installation costs, maintenance and repair costs, cost of electricity consumed, and savings from reduced fuel consumption.

- **Assumptions and data:** A vehicle lifetime of 12 years is assumed in this analysis. EVSE capital costs and installation costs are based on subject matter expert assumptions and DOE AFDC data. Vehicle capital costs and maintenance and repair costs are based on data from AFLEET.

Increase Adoption of Light-Duty Electric Vehicles

Description

This strategy includes increasing the adoption of light-duty electric passenger vehicles (including private and municipal fleet vehicles) by following the Pennsylvania EV Roadmap, using a ZEV mandate, providing education and outreach, and offering additional or modified incentives through AFIG, the Alternative Fuel Vehicle (AFV) Rebate, and the Driving Pennsylvania Forward program.[46] This strategy also includes approaches for providing access to electric vehicles and charging infrastructure in low-income communities, multi-family units, and workplaces through ad-hoc programs.

Method, Data and Key Assumptions

- **EV Market Penetration**: EVs will represent 20%of the light-duty market share by 2030, rising to 70%by 2050. The target is based on the Pennsylvania DEP Pennsylvania Electric Vehicle Roadmap report, with consideration for the current market share.
- **Strategy Layering:** This measure will use Transportation Strategy #1 as a baseline to avoid double-counting emissions reductions.
- **Emissions Accounting:** Changes in electricity consumption are accounted for in the electricity generation sector and then reported out for informational purposes here (similar to the buildings sector). Other fuel reductions and related emission reductions are represented in this strategy. Emissions focus on tailpipe emissions from vehicles.

Applicable Emission Factors

- **GHG:** GHG emission factors are from the State Inventory Tool Mobile CO2FFC Module. Electricity emission factors come from ICF's IPM.
- **Air Quality:** Air quality emission factors are ICF-developed factors based on MOVES runs provided by DEP.

Costs and Benefits Analysis

- **Components:** The analysis includes capital costs of vehicles and charging infrastructure, installation costs, maintenance and repair costs, cost of electricity consumed, and savings from reduced fuel consumption.
- **Assumptions and data:** A vehicle lifetime of 12 years is assumed in this analysis. EVSE capital costs and installation costs are based on subject matter expert assumptions and DOE AFDC data. Vehicle capital costs and maintenance and repair costs are based on data from AFLEET.

[46] https://www.dep.pa.gov/Business/Air/Volkswagen/Pages/Driving-PA-Forward-Grant-and-Rebate-Awards.aspx

Implement a Low Carbon Fuel Standard (LCFS)

Description

This strategy includes decreasing the carbon intensity of transportation fuels and provide an increased supply and range of alternative fuels through a system of credits, similar to the California LCFS Program. This expands on the ethanol and biodiesel requirements already in place in Pennsylvania, and would apply to zero-emission vehicles.

Method Data and Key Assumptions

- **Energy Savings:** As part of this strategy, changes in fuel consumption and associated emissions from fuel switching to i) renewable diesel, ii) natural gas (i.e., compressed natural gas (CNG)), and iii) electricity from gasoline and diesel are estimated. Annual changes in fuel consumption were estimated by linearly interpolating reductions in carbon intensity of the fuel mix in accordance with the 8% and 20% carbon intensity reduction targets by 2030 and 2040, respectively. The analysis team assumed total fuel consumption to be equivalent to BAU fuel consumption.
- **Strategy Layering:** This is the final measure to be implemented, and reductions from other transportation strategies are layered into baseline fuel consumption used to model the LCFS.
- **Emissions Accounting:** Changes in electricity consumption are accounted for in the electricity generation sector and then reported out for informational purposes here (similar to the buildings sector). Other fuel reduction and related emission reductions are represented in this strategy.

Applicable Emission Factors

- **GHG:** GHG emission factors are from the State Inventory Tool Mobile CO2FFC Module. Electricity emission factors come from ICF's IPM.
- **Air Quality:** Air quality emission factors are taken from ICF-developed factors based on MOVES runs provided by DEP.

Costs and Benefits Analysis

- **Components:** This analysis includes the compliance cost based on low carbon fuel programs in California and Oregon, and determining the aggregate cost based on the amount of gasoline and diesel fuel use.
- **Assumptions and data:** Historical cost data from California and Oregon will be used to inform cost ranges.

Industrial Sector

Increase Industrial Energy Efficiency and Fuel Switching

Description

This strategy includes leveraging existing DEP programs (e.g., the Energy Efficiency, Environment, and Economics [E4] Initiative) and implementing the types of actions outlined in the Clean Energy Program Plan developed by DEP's Energy Programs Office. This strategy will rely on broader tools such as virtual trainings and expanded partnerships to reach smaller and hard to access industries. In addition to energy efficiency measures, industrial opportunities that fuel switch from fuel oil to natural gas and measures to switch natural gas to electricity are included in this strategy.

Method, Data and Key Assumptions

- **Energy (Electricity and Natural Gas Savings:** An internal ICF sector based industrial carbon reduction study was used to evaluate energy efficiency potential of the various industrial sectors. The various energy efficiencies were allocated to the total industrial proportionally to the GHG contribution from various sectors as determined by the EPA's 2018 Facility Level Information on GreenHouse Gases Tool (FLIGHT) as part of the EPA's GHG Reporting Program. Industrial GHG emissions from underground coal mines were eliminated entirely by 2050. For the proportion of sector-based emissions not covered by the sector study a factor of 25% energy efficiency potential was used by 2050 was used. Total energy efficiency potential was ramped up to 2050 measures. Strategies were phased in using an assumed lifecycle of 10 years.
- **Fuel Switching and Electrification:** Fuel oil industrial emission were transitioned to natural gas for 80% of the total fuel oil use by 2050. Electrification of industrial natural gas use was applied for 20% of total natural gas use using the same methodology as Building Sector Strategy #4, for the portion of industrial activity and using an 18% efficiency factor.
- **Strategy Layering:** Reductions from this strategy were applied before Fuels Supply Strategy #2 (increased CHP).
- **Emissions Accounting:** Emissions savings as a result of energy efficiency improvements are accounted for in the industrial sector.

Applicable Emission Factors

- **GHG:** GHG emission factors for electricity come from IPM and other relevant sources or were calculated using assumptions from onsite generation projects. The analysis team also accounted for reduced electricity emissions that result from combined heat and power (CHP) generation and updated the emissions factor for CHP as more projects come online. The team calculated a blended gas supply emission factor over time based on the available supply of renewable natural gas (see Fuel Supply Strategy #1) and overall gas demand across the state. Other fuel emission factors come from the U.S. Inventory and 2006 IPCC Guidelines for National Greenhouse Gas Inventories (consistent with the State Inventory Tool).
- **Air Quality:** Air Quality emissions factors for electricity come from IPM. Emissions factors for natural gas, coal, fuel oil, and other fuels come from EPA AP-42 Fifth Edition Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources; and Emission Factor Supporting Documentation for the Final Mercury and Air Toxics Standards. Mercury Air Toxic Standards (MATS).

Costs and Benefits Analysis

- **Components:** Energy Efficiency Potential was estimated from an internal ICF industrial sector-based energy efficiency study. Factors specific to the following sub-sectors were applied. Pulp and Paper, Iron and Steel, Bulk Chemical, Cement and Lime, Petroleum Refining, and Aluminum and Glass subsector energy efficiency values were used. Emissions from coal mines were eliminated by 2050 and a 25% energy efficiency factor was applied to the remaining emissions from the industrial sector. Program costs for electricity and natural gas reductions were estimated using the same methodologies as applied to the Building Sector Strategies 2 and 3.

Fuel Supply

Increase Production and Use of Biogas/Renewable Gas

Description

This strategy includes increases in the production and use of biogas/renewable gas from sources such as coal mines, agriculture, wastewater, and landfills. This strategy considers the potential for renewable gas and specific applications within Pennsylvania and regionally across a number of feedstocks, as identified in the 2019 American Gas Foundation renewable natural gas (RNG) report, Penn State University's RNG analysis, and ICF's Pennsylvania RNG database. Fuels will be supplied through the existing pipeline network and will supply end uses, not including power generation.

Method, Data, and Key Assumptions

- **Potential for RNG:** Based on the analysis team's evaluation for the American Gas Foundation in 2019, there are various feedstock options for considering biogas and renewable gas in Pennsylvania. These options and their potential are listed below. The potentials are maximum, and the analysis team applied criteria to reduce the amount of supply available by 2050 and also phase in availability over the 2020 to 2050 time period. In particular, thermal gasification feedstocks are not available in the analysis team's modeling until 2030.

Total (Bcf)	PA Total
Animal Manure	56.4
Food Waste	3.8
Landfill Gas	60.9
WRRFs	4.0
Anaerobic Digestion sub-total	125.2
Agriculture Residue	14.4
Energy Crops	74.5
Forestry Residue	7.5
MSW	33.3
Thermal gasification sub-total	129.7
Total	254.8

- **Uses of RNG:** The analysis team assumed that some feedstocks for RNG will be used in direct CHP applications, but that the majority of available RNG supply will be injected into the pipeline to decarbonize the gas supply in Pennsylvania. As a first step, the analysis team considered RNG use for CHP; landfill gas will not be used for CHP and some portion of anaerobic digester gas will be used for CHP (most likely at water resource recovery facilities (WRRFS) and large farms). The remainder of available RNG is distributed proportionally across the end use sectors of residential and commercial buildings, industrial, and transportation based on total gas btu need.
- **Strategy Layering:** This action interacts with Electricity Generation Strategy #2 (carbon-free grid), Fuel Supply #2 (CHP), and all strategies that result in continued natural gas use (i.e., the industrial, residential, commercial, and transportation sectors).
- **Emissions Accounting:** GHG emissions reductions for this strategy are reflected in end use sectors and the power sector, as well as for Fuel Supply Strategy #3, which could focus on reduction of methane emissions from distribution systems for gas.

Applicable Emission Factors

- **GHGs:** The analysis team assumed that RNG is carbon neutral.
- **Air Quality:** The team used the Argonne National Laboratory's GREET Model to determine air quality emission factors for biogas/renewable natural gas.

Costs and Benefits Analysis

- **Components:** This cost analysis includes capital expenditures and operational costs for RNG production from various feedstock and technology pairings described in the AFG report.
- **Assumptions and data:** The analysis includes the costs of bringing RNG supply from various feedstocks on to the pipeline system. ICF evaluated the potential costs associated with the deployment of each feedstock and technology pairing. The cost of deployment includes a series of assumptions regarding the production facility sizes, gas upgrading and conditioning and facility upgrading costs, compression, and interconnect for pipeline injection. The costs used in this analysis are dependent on a variety of assumptions, including feedstock costs, the revenue that might be generated via byproducts or other avoided costs, and the expected rate of return on capital investments. ICF finds that there is potential for cost reductions as the RNG for pipeline injection market matures, production volumes increase, and the underlying structure of the market evolves.

Incentivize and Increase Use of Distributed Combined Heat and Power (CHP)

Description

This strategy includes incentivizing and increasing the use of distributed CHP with microgrids, particularly for high-value applications such as critical facilities (e.g., hospitals) and industrial facilities.

Method, Data and Key Assumptions

- **Energy:** While most CHP systems use natural gas, they are substantially more efficient than separate heat and utility-delivered electricity. With the improved efficiency, there is a net reduction in fossil fuel consumption when CHP is implemented, provided that marginal grid generators are using fossil fuels. In the BAU case, current and planned CHP installations from ICF's CHP Installation Database are maintained through 2050. Other cases evaluate CHP potential and expected adoption according to economic factors, utility incentives, and technical potential for new CHP installations in Pennsylvania, referenced from ICF's CHP Technical Potential Database.
- **Strategy Layering:** This strategy will be applied after the Industrial energy efficiency strategy and Fuel Supply #1 (Bio/Renewable Gas).
- **Emissions Accounting:** Emissions savings appear in two places—emissions related to kWh are accounted for in the electricity generation sector, and emissions related to displaced gas or fossil use appear in the buildings sector. Emissions from electricity consumed by residential and commercial buildings are reported for informational purposes only and not included in emissions totals. These informational emission reductions are calculated using marginal emission factors for the grid over time.

Applicable Emission Factors

- **GHG:** GHG emission factors for electricity will come from IPM. The analysis team calculated a blended gas supply emission factor over time based on the available supply of renewable natural gas (see Fuel Supply 1 measure) and overall gas demand across the state. Other fuel emission factors come from the U.S. Inventory and 2006 IPCC Guidelines for National Greenhouse Gas Inventories (consistent with the State Inventory Tool).
- **Air Quality:** Air Quality emissions factors for electricity come from IPM. Emissions factors for natural gas, coal, fuel oil and other fuels come from EPA AP-42 Fifth Edition Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources; and Emission Factor Supporting Documentation for the Final Mercury and Air Toxics Standards. Mercury Air Toxic Standards (MATS). As applicable biogas air quality factors will also be used (see Fuel Supply 1).

Costs and Benefits Analysis

- **Components:** The cost analysis includes energy costs, including electricity and natural gas.
- **Assumptions and data:** Costs for high load factor CHP applications are based on state average electricity and natural gas prices for the commercial sector to estimate energy costs. Electricity and gas escalation rates for the commercial sector in the AEO Middle Atlantic reference case were used to estimate energy costs through 2050. For CHP installations 1–20 MW in size, 2019 state average industrial sector electricity and gas prices were used, and for potential installations over 20 MW, gas prices were reduced to the state average city-gate price, plus $2 per MMBtu for pipeline transportation. For all potential installations over 1 MW in size, electricity and gas escalation rates for the

industrial sector in the AEO Middle Atlantic reference case were used to estimate energy costs through 2050.

Reduce Methane Emissions Across Oil and Natural Gas Systems

Description

This strategy includes the implementation of practices to reduce methane emissions from upstream and midstream oil and gas operations. This strategy reflects reductions of methane emissions as a co-benefit of the ongoing rulemaking to curb VOC emissions from oil and gas operations. It also includes voluntary mitigation technologies that would be implemented across operations to further reduce methane emissions beyond regulatory requirements.

Method, Data and Key Assumptions

- **Emissions Reductions:** This action focuses on determining achievable voluntary reductions from upstream and midstream oil and gas operations. To establish an initial emissions source level baseline and consider the impacts from recently proposed oil and gas methane regulations,[47] the analysis team leveraged a DEP analysis which quantified these estimates using 2017 as the base year. DEP's analysis utilized oil and gas company data from DEP's Air Emissions Report[48] and assumptions which determine expected reduction impacts from the implementation of the proposed regulations on individual emission sources. For this analysis, ICF first considered emissions from DEP's baseline 2017 data for various emission sources. Expected regulatory reduction impacts were then applied (also per DEP analysis) to arrive at a baseline, net emissions estimate after regulatory control. ICF then considered the implementation of mitigative actions for certain sources to determine additional, achievable voluntary reductions beyond regulatory control. These voluntary reductions were calculated by utilizing an assumed applicability (e.g., technical limitations may exist at certain sites), reduction effectiveness, and the ability for a given operator to achieve the mitigation action in the base year. Each of the above assumptions are based on ICF input. Because DEP estimates are provided for unconventional sources only, conventional estimates were assumed to match that of unconventional sources, similar to the 2018 CAP. All results generated in this analysis were then scaled to match upstream SIT estimates to give appropriate segment proportions and to match BAU case estimates.
- **Annualization and Projection of Emission and Reduction Results:** AEO 2020 reference case oil and natural gas production values were used to project 2017 baseline estimates to 2050. Certain source emissions were driven using forecasted natural gas production, while others were driven using a combination of oil/natural gas production (combined BTU). AEO estimates utilized in this analysis represent the Middle Atlantic and East supply regions, respectively. Forecasted natural gas prices used when determining recovered revenue discussed below also represent the East supply region in the 2020 AEO. Reductions in future years were determined by first removing achieved reductions in the prior year, then applying applicable reduction percentages to the projected source level net emission estimate in the following year. The analysis team assumed all operators would have the ability to implement voluntary mitigative action by 2050.

Costs and Benefits Analysis

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[47] Pennsylvania DEP; https://www.dep.pa.gov/Business/Air/pages/methane-reduction-strategy.aspx.

[48] Pennsylvania DEP Air Emissions Report; http://cedatareporting.pa.gov/reports/powerbi/Public/DEP/AQ/PBI/Air_Emissions_Report.

- **Associated Costs:** Capital and operating costs were determined by applying voluntary reduction volumes as determined above to an associated reduction amount per activity. This determines the number of required actions (and associated capital and operating costs) based on the appropriate volume of voluntary reductions for each source. Recovered revenue is calculated using voluntary reduction volumes from activities where capture is possible.

Electricity Generation

Maintain Nuclear Generation at Current Levels

Description

This strategy includes implementing a policy to maintain nuclear generation at current levels. This would assume an 80-year lifetime extensions for plants currently in operation; all plants currently in operation would stay online through 2050 at least with this extension. Nuclear generation is also incorporated into the carbon emissions free grid strategy below, therefore the costs and benefits associated with this strategy are incorporated in the carbon free grid strategy.

Method, Data and Key Assumptions

- **Energy:** Current (as of 2020) Nuclear generation levels are held constant after these plants are closed. To model a policy action that restores these units to service for the study period, their capacity and generation are added back to the PJM fleet. To balance the overall electricity generation totals over the years (i.e., to not create new generation on top of the business-as-usual scenario), the team assumed that nuclear electricity generation displaces coal and natural gas electricity generation in future years.
- **Strategy Layering:** This action is applied before Electricity Generation Strategy #2 (carbon-free grid).
- **GHG Accounting:** GHG emission accounting for this strategy used IPM Reference Case output as a baseline, and projected GHG reductions from maintaining nuclear as a source of electricity generation at current levels.

Applicable Emission Factors

- **GHGs:** GHG emission factors come from IPM.
- **Air Quality:** Air quality emission factors come from IPM.

Costs and Benefits Analysis

- The cost analysis for this strategy is included as part of the cost analysis for Electricity Generation Strategy #2.

Create a Carbon Emissions Free Grid

Description

This strategy includes expanding the Alternative Energy Portfolio Standard (AEPS) to achieve a carbon free grid. Tier 1 targets and the solar carve out are expanded, and additional eligible energy sources are added including nuclear, storage, and fossil with carbon capture and sequestration. Tier 2 sources are maintained as part of the portfolio of options to meet the 100% target. To implement this successfully, additional efforts will need to be employed, such as strategies to expand the development of solar and wind projects across the Commonwealth (both grid-scale and distributed), legislation to help develop a robust solar industry at the distributive- and grid-level, and strategies that increase the value of solar renewable energy credits (SRECs).

Method, Data and Key Assumptions

- **Method:** The team used IPM to determine the generation through 2050 that will result in a clean grid (100% AEPS requirement by 2050), based on several constraints:
    - The solar carve out is assumed to be in line with the Finding Pennsylvania's Solar Future Plan initially, and then will go beyond it in 2030 through 2050.
    - Generation for other eligible renewables from 2020 through 2050 were developed using IPM.
    - All solar Alternative Energy Credits (AECs) for solar and Tier 2 resources are assumed to come from in-state generation, as required through legislation. DEP may consider limiting additional resources in-state in the modeling should additional reductions be needed to achieve a state-wide 80% reduction by 2050.
- **Strategy Layering:** This action is applied after Electricity Generation Strategy #1 (maintain nuclear generation at current levels). This action interacts with other CAP actions that impact electricity use (e.g., buildings, transportation, and CHP), as the electricity consumption emission factor will change from grid changes in the Commonwealth.
- **GHG Accounting:** GHG emission accounting for this strategy used IPM Reference Case emissions as a baseline and projected GHG reductions in Pennsylvania from transitioning to a clean grid.

Applicable Emission Factors

- **GHGs:** GHG emissions come from IPM.
- **Air Quality:** Emissions for NO_x and SO_2 come from IPM.

Costs and Benefits Analysis

- Refer to EPA's Power Sector Modeling Platform 2020 Reference Case Incremental Documentation for information on the cost analysis associated with this strategy.

Agriculture

Use Programs, Tools, and Incentives to Increase Energy Efficiency for Agriculture

Description

This strategy includes programs, tools, and incentives to increase energy efficiency for agricultural end uses such as refrigeration, ventilation, and lighting.

Method, Data and Key Assumptions

- **Baseline Farm Energy Use:** Annual baseline farm energy consumption used data from a report by EnSave titled "Energy Use, Energy Savings, and Energy Efficiency Policy Recommendations for Pennsylvania Agriculture."[49] The report provides estimates for annual electricity and fuel usage for dairy, beef, poultry, swine, orchard, greenhouse, and crop farming. These estimates are based on EnSave's Farm Energy Audit Tool (FEAT) database. This baseline was disaggregated from the EIA BAU data to ensure alignment and to prevent double counting.
- **Energy Efficiency Measures:** EnSave's report provides a list of recommended energy efficiency strategies that offer farmers the most energy savings potential and reduced fuel consumption. Examples of potential strategies include: implementing LED lighting and lighting controls, high efficiency circulation fans, high efficiency scroll compressors, wall insulation, and compressor heat recovery systems. The analysis team assumed that the achievable savings would be 10% of the total technical annual savings potential. The strategies were modeled to have a measure lifetime of 10 years, and the associated energy savings are also modeled to run out after 10 years.
- **GHG Accounting:** Emissions savings as a result of energy efficiency improvements that affect electricity consumption are accounted for in the electricity generation sector (reduced generation = reduced emissions). Emissions from electricity consumed by farms were reported for informational purposes only and are not included in total emissions reductions.
- **Strategy Layering:** This strategy uses BAU energy consumption estimates from the industrial sector. Emission reductions from this strategy are assumed to be unique and do not overlap with the reductions modeled in the industrial energy efficiency measure.

Applicable Emission Factors

- **GHG:** GHG emission factors for electricity come from IPM, which accounts for reduced electricity emissions that result from combined heat and power (CHP) generation and other generation-based changes. Other fuel emission factors come from the U.S. Inventory and *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (consistent with the State Inventory Tool).
- **Air Quality:** Air Quality emissions factors for electricity come from eGRID data. Emissions factors for natural gas, coal, fuel oil, and other fuels come from EPA AP-42 Fifth Edition Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources; and Emission Factor Supporting Documentation for the Final Mercury and Air Toxics Standards. Mercury Air Toxic Standards (MATS).

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[49] EnSave report "Energy Use, Energy Savings, and Energy Efficiency Policy Recommendations for Pennsylvania Agriculture."

Provide Trainings and Tools to Implement Agricultural Best Practices

Description

This strategy includes trainings and tools to implement agricultural best practices, such as those focused on no-till farming practices, integrated farm management and conservation planning, and soil management. Practices could include rotational grazing, silvopasture, and organic and regenerative agricultural methods. This strategy also includes researching crops that will be most appropriate for future climate conditions.

Method, Data and Key Assumptions

- **Total Acres Planted**: The analysis team assumed the total agricultural acres planted in Pennsylvania will increase by approximately 2% annually based on the U.S. Department of Agriculture (USDA) Pennsylvania Tillage Survey statistics for 2013 and 2014.
- **Acres Planted by Crop**: The team assumed that the percent of acres planted by crop is consistent with the average percent of acres planted by crop from 2011 to 2019, as obtained from the USDA National Agricultural Statistics Service QuickStats database.[50]
- **Tillage Adoption**: The team assumed conventional tillage acres will transition to reduced tillage acres, and reduced tillage acres will transition to no-tillage acres.[51]
    - **No-Till Adoption:** According to USDA's Pennsylvania Tillage Survey statistics, no-till acres increased by approximately 8.5% from 2013 to 2014. The analysis team conservatively assumed no-till acres in Pennsylvania will increase by approximately 6% annually based on the slower, historical trend of no-till adoption. The team also assumed that no-till adoption will reach a maximum of 98% of acres planted by 2024.
    - **Reduced Till Adoption:** According to USDA Pennsylvania Tillage Survey statistics, reduced till acres decreased by approximately 16% from 2013 to 2014. For this analysis, the team assumed this trend will continue through 2020. After 2020, reduced till acres will decrease by approximately 30,000 acres annually until no-till adoption reaches 98% of total acres planted in 2024. After 2024, the share of reduced till acres will remain constant at approximately 1% of total acres planted.
    - **Conventional Till:** Conventional till acres were assumed to equal the difference between total acres planted, no-till acres, and reduced till acres.
- **Carbon Sequestration:** Emission reductions by crop/tillage practice for USDA's Northeast region come from the USDA's "Greenhouse Gas Mitigation Options and Costs for Agricultural Land and Animal Production within the United States" report. Emission reductions by crop/tillage practice are based on Pennsylvania's average share of acres planted by crop from 2011 to 2019.
- **Changes in Yield:** Changes in yield by crop/tillage practice for USDA's Northeast region come from USDA's "Greenhouse Gas Mitigation Options and Costs for Agricultural Land and Animal Production within the United States" report. Changes in yield by crop/tillage practice are based on Pennsylvania's average share of acres planted by crop from 2011 to 2019.

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[50] See: https://quickstats.nass.usda.gov/. Accessed July 4, 2018.

[51] In 2013, farmland comprised 16.6% conventional till acres, 21.5% reduced till acres, and 61.9% no till acres comprised. USDA. 2015. Tillage Practices with Updated Alfalfa Seedings and Final Acreages. Accessed July 3, 2018/. Available online at: https://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Survey_Results/tillage%202014%20jan%2020125.pdf.

- **Changes in Production and Revenue**: The analysis team multiplied estimates of reduced yield by the projected estimates of conventional, reduced, and no-till acres in Pennsylvania to obtain reduced production estimates. The team multiplied production by weighted revenue (dollars per short ton of production).
- **Strategy Layering:** This strategy does not require any layering.

Applicable Emission Factors

- GHG emission factors for electricity come from IPM, which accounts for reduced electricity emissions that result from changes in generation sources. Carbon sequestration factors for various crop types are based on estimates from USDA's "Greenhouse Gas Mitigation Options and Costs for Agricultural Land and Animal Production within the United States." Other fuel emission factors come from the U.S. Inventory and *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (consistent with the State Inventory Tool).
- Air quality emission factors for electricity come from eGRID data. Emissions factors for natural gas, fuel oil, LPG, and other fuels come from EPA AP-42 Fifth Edition Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources; and Emission Factor Supporting Documentation for the Final Mercury and Air Toxics Standards. Mercury Air Toxic Standards (MATS).

Costs and Benefits Analysis

- **Components:** This strategy includes estimates of savings from reduced fuel consumption as well as costs incurred from capital expenditures on a per acre basis, as well as operation and maintenance costs by crop, fertilizer usage, and tillage practice.
- **Assumptions and data:** The team estimated fuel savings by applying USDA regional estimates of fuel consumption ($/acre) for various tillage practices to the projected estimates of conventional, reduced, and no-till acres in Pennsylvania. The analysis team assumed diesel, natural gas, liquefied petroleum gas (LPG), motor gasoline, and kerosene represented 73, 23, 2, 3, and <1% of consumption on a BTU basis, respectively, based on consumption data for the Agriculture economic sector from U.S. EPA's 1990-2016 Inventory of U.S. Greenhouse Gas Emissions and Sinks.

  The analysis team relies on estimates of capital costs per acre from University of Illinois' 2017 Machinery Cost Estimates. The team then applies per acre capital costs to the projected estimates of conventional, reduced, and no-till acres in Pennsylvania.

  The analysis team weights USDA Pennsylvania O&M plowing, planting, drilling, and spraying costs by crop, fertilizer usage, and tillage practice. The team then applies the weighted O&M costs per acre to the projected estimates of conventional, reduced, and no-till acres in Pennsylvania.

LULUCF

Land and Forest Management for Natural Sequestration and Increased Urban Green Space

Description

This strategy include managing and increasing forest cover, particularly of oak-hickory forest, through a reduction of forest removal from 130-yr rotation, and additional converting abandoned mined lands to forests.

Method, Data and Key Assumptions

- **Forest Carbon and Urban Trees:** The U.S. Forest Service published a report in April 2020 that summarizes the amount of CO_2 emissions and removals from forest land, woodlands, and urban trees at the state-level. This publication served as a starting point for determining how much carbon is currently being sequestered by forest and urban tree cover in Pennsylvania.[52]
- **Cropland and Soil Management:** Although forests and urban trees are typically the largest land-based stock of carbon, croplands also have the potential to store significant quantities of carbon. The project team worked with Penn State to identify potential land management practices that could be easily modeled in the analysis framework. Additionally, the project team ensured that this strategy does not overlap with Agriculture Strategy #2.
- **Land Sequestration Strategies:** Researchers from Penn State identified two priority areas for increasing carbon sequestration from natural lands in Pennsylvania: converting abandoned mine lands and marginal croplands to forest land. The team from Penn State developed an analysis for carbon sequestration potential by applying these strategies to two types of forests commonly found in Pennsylvania: oak-hickory and maple-beech-birch. ICF used the sequestration estimates for the oak-hickory strategy since these are the primary forests in which abandoned mine lands are found.
- **Emissions Accounting:** GHG emission accounting for this strategy will use the estimates from the State Inventory Tool (SIT) as a baseline and project CO_2 reductions from the proposed changes in land-use practices.

Applicable Emission Factors

- GHG and Air Quality emission factors are based on the State Inventory Tool's LULUCF module.

Costs and Benefits Analysis

- Components: XXX
- Assumptions and data: XXX

[52] Greenhouse gas emissions and removals from forest land, woodlands, and urban trees in the United States, 1990-2018. Resource Update FS-227. Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station. 5 p. https://doi.org/10.2737/FS-RU-227.

Macroeconomic Modeling Methodology

The analysis team used a method to estimate the macroeconomic impacts similar to that used in the 2018 CAP analysis. The macroeconomic modeling (e.g., changes in jobs) was conducted using the REMI PI+ model. This is a structural economic forecasting and policy analysis model that integrates several analytic techniques including input-output, computable general equilibrium (CGE), econometric, and economic geography methodologies. REMI is a dynamic model with forecasts and simulations to include behavioral responses to wage, price, and other economic factors. It can be used for estimating national-, regional-, and state-level impacts of any policy changes. The dynamic modeling framework supports the option to forecast how changes in the economy, and adjustments to those changes, will occur on an annual basis.

REMI functions by forecasting two states of the world. The first is the state of the regional economy under some standard assumptions of employment and population changes. This first forecast is referred to as the control forecast. The second forecast, in which the model user incorporates the desired policy changes, is referred to as the alternative forecast or the simulation. The difference between the two forecasts would be the estimated effect of the policy. Policy changes that were input into REMI were modeled by the analysis team as described above.

Macroeconomic factors are available from REMI, which capture multiple benefit and cost effects, including employment, gross state product, and personal income. This is useful as a richer set of indicators. To better understand the macroeconomic impacts of the CAP, DEP and the analysis team examined the strategies in greater detail, by estimating the impacts on employment, gross state product (GSP), and personal disposable income for commonwealth residents.

The analysis team utilized the REMI model to estimate these macroeconomic impacts by using individual action-level inputs to model the CAP strategies. These inputs vary by sector.

- **Building sector:** Revised building codes and energy efficiency incentives for the residential and commercial sectors, resulting in modeling capital expenditures and electricity savings for consumers and businesses.
- **Transportation sector:** Investments in electric vehicles (a negative impact on consumer budgets) resulting in an increase in electricity bills, but gasoline and diesel savings and lower maintenance costs.
- **Industrial sector:** Capital expenditures for efficient appliances and electrification of the manufacturing process results in changes to electricity use (e.g., an increase for electrification but a decrease for energy efficient appliances) and bill savings from reduced fuel usage (e.g., from reduced natural gas consumption as a result of electrification).
- **Fuel supply sector:** Impacts from an increase in waste digester usage to create energy for sectors such as agriculture, wastewater, landfills, and coal mines. These technologies require capital investment but drive energy savings through the creation of renewable natural gas.
- **Electricity generation sector:** Investments in renewable energy (e.g., wind and solar) and shifts away from fossil fuels (e.g., coal and natural gas) using the Jobs and Economic Development Impact models from National Renewable Energy Laboratory. Utilizing IPM to estimate ratepayer impacts from changing generation mix, credit costs, and carbon price impacts.
- **Agricultural sector:** Savings on diesel and gas expenditures from encouragement of best agricultural practices.

Public Health and Equity Analysis

1 # Adaptation Strategy Methodology

2 - 1-page methodological details and detailed results for each adaptation action