Pennsylvania Climate Action Plan

Strategies for government, business, agriculture, and community leaders—and all Pennsylvanians

pennsylvania DEPARTMENT OF ENVIRONMENTAL PROTECTION

ICF

PennState

HAMEL ENVIRONMENTAL CONSULTING

7200-RE-DEP5418 9/2021 G2515

ACKNOWLEDGEMENTS AND DISCLAIMER

This material is based on 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 plan that was prepared in response to the Pennsylvania Climate Change Act (Act 70 of 2008), which requires the Department of Environmental Protection (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 plan and the analyses contained in it were prepared by the Pennsylvania DEP with support from ICF, Penn State University and Hamel Environmental Consulting.

For More Information:

David Althoff Jr.
Director, Energy Programs Office
Department of Environmental Protection
Rachel Carson State Office Building
400 Market Street
Harrisburg, PA 17105-8772
Phone: 717.783.0542
Email: dalthoff@pa.gov
www.dep.pa.gov/climate

Cover Photos:

Top: Center for Sustainable Landscapes at Phipps Conservancy and Botanical Gardens (photo credit: Denmarsh Photography, Inc.)

Bottom, Left to Right: Electric car charging; Benjamin Rush State Park tree planting, Philadelphia, PA; Wind farm in central Pennsylvania (photo credit: Andy Fogelsonger); Solar panels at the Tom Ridge Environmental Center, Presque Isle, PA

PENNSYLVANIA CLIMATE ACTION PLAN 2021

Strategies for government, business, agriculture, and community leaders—and all Pennsylvanians

September 2021

MESSAGE FROM GOVERNOR WOLF

The Climate Imperative

As I've seen firsthand in communities statewide, Pennsylvania is undergoing more extreme weather events, from flooding and tornadoes this month in Philadelphia and across southeast and southcentral counties, to record water levels in Lake Erie in 2019, to flooding that led to U.S. Department of Agriculture disaster declarations in 33 counties in 2018.

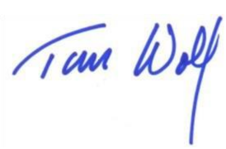
Increasingly frequent, these events are buffeting Pennsylvania with deep recurring socioeconomic costs: public health stresses; evacuations and closings; flooded, buckled, and washed-out roads and bridges; downed trees and power outages; large-scale cleanups; and destroyed homes, businesses, and harvests.

We must move now out of reactive mode on climate change. Leadership across sectors requires knowledge, tools, and proactive approaches to climate change to protect Pennsylvanians' health and safety, economy, infrastructure, farms, businesses, recreation, and environmental resources. In addition to preparing for and adapting to the level of impacts we're already experiencing, we must significantly lower greenhouse gas emissions to prevent worsening impacts.

In 2019, I set the first ever statewide goals to reduce greenhouse gas emissions: 26 percent lower by 2025 and 80 percent lower by 2050, compared to 2005, which is the standard baseline. I've charted a course for Pennsylvania to join 10 Northeast states in the Regional Greenhouse Gas Initiative, the cap-and-invest program that reduces carbon dioxide emissions from electric power plants. Revenue from carbon allowance auctions will be targeted to traditional energy-based communities and Environmental Justice areas across Pennsylvania and to further reduce carbon emissions statewide.

I also mandated that state agencies lead by example, increasing sustainability while saving taxpayers money and creating jobs in Pennsylvania's clean energy economy. In addition to aggressively stepping up energy efficiency measures, we launched an initiative in 2021 to get nearly 50 percent of state agencies' electricity from seven new solar energy arrays to be built around the state by January 2023.

I urge leaders across government, business, agriculture, academia, and community organizations—and all Pennsylvanians—to join in making climate change a top priority. It is only with your commitment, collaboration, and action, large scale or small, that Pennsylvania will meet the climate imperative. Throughout history, Pennsylvania has led the nation in every era of energy innovation. We can and must lead now. Pennsylvania Climate Action Plan 2021 tells us how.



September 22, 2021

MESSAGE FROM SECRETARY PATRICK MCDONNELL

Tools to Lead on Climate Action

Slowing down future climate change and adapting to changes that are already happening present a challenge on a scale that can seem overwhelming. Where to start?

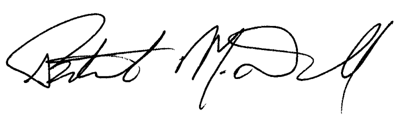
Pennsylvania Climate Action Plan 2021 is where to start. Here you'll find statewide data on and trends in greenhouse gas emissions from every sector: electricity generation, transportation, industry, agriculture, residential and commercial buildings, and more.

A suite of 18 strategies is recommended that—if started now—will meet our statewide greenhouse gas emissions goals for 2025 and 2050. For each strategy, the emission reductions, costs, and benefits in jobs and economic growth are quantified, and health and social benefits are analyzed. Supplemental strategies are also recommended to bolster efforts toward greenhouse gas reductions.

In addition, Pennsylvania Climate Action Plan 2021 identifies priority areas to focus our preparation and adaptation: public health, overburdened and vulnerable populations, agriculture, recreation and tourism, infrastructure, and forests, ecosystems, and wildlife.

Pathways to adaptation are mapped out that will enable us to lessen negative impacts and capitalize on any potential opportunities created by climate change.

After getting an overview from this booklet, head to www.dep.pa.gov/climate. There you can review the complete Pennsylvania Climate Action Plan 2021 in depth to inform your policy, planning, and program decision making. You'll also find helpful related resources, including Pennsylvania Climate Impacts Assessment 2021, the Local Climate Action Program, statewide data on greenhouse gas emissions, as well as on job growth and workforce development needs in clean energy industries, and many more tools to lead on climate action in Pennsylvania.



September 22, 2021

TABLE OF CONTENTS

List of Figures

List of Tables

EXECUTIVE SUMMARY

Introduction

Pennsylvania established its first statewide policy on climate change in the Pennsylvania Climate Change Act of 2008 (Act 70). The Act requires the Department of Environmental Protection (DEP) to compile an annual greenhouse gas (GHG) inventory, develop a voluntary GHG registry, and develop a climate action plan (CAP) and impacts assessment and update them every three years. Act 70 also establishes the Climate Change Advisory Committee (CCAC) to advise DEP during CAP and Impacts Assessment development. Working with the committee, DEP has issued several climate action plans and impacts assessments in the intervening years.

Act 70 Requirements

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

Executive Order 2019-01

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

Governor Tom Wolf issued an executive order in 2019 that established a Pennsylvania climate goal of a 26% reduction in net GHG emissions statewide by 2025 and an 80% reduction by 2050, from 2005 levels. It also reestablished the GreenGov Council to assist state agencies in incorporating environmentally sustainable practices into policy and planning decisions.

This 2021 Climate Action Plan presents GHG reduction strategies that could realize the executive order's emission reduction goals. It also maps out strategies for adapting to the impacts of climate change, based on the 2021 Pennsylvania Climate Impacts Assessment[1].

Within the last two decades, the Commonwealth has created energy policy and program actions that have complemented and supported Act 70's overall goals. For example, the Alternative Energy Portfolio Standard (AEPS) that increased electric utilities' purchases of renewable power, and Act 129 that continue to require electric utilities to meet customer energy savings targets, were in place when the first CAP was published. Given the many efforts which can be undertaken across state government, local governments, and in the private sector and other organizations, the CAP process allows DEP to identify, coordinate, integrate, and leverage a

---

[1] PA Department of Environmental Protection (2021). Pennsylvania Climate Impacts Assessment 2021. www.depgreenport.state.pa.us/elibrary/GetDocument?docId=3667348&DocName=PENNSYLVANIA CLIMATE IMPACTS ASSESSMENT 2021.PDF %28NEW%29 4/30/2023

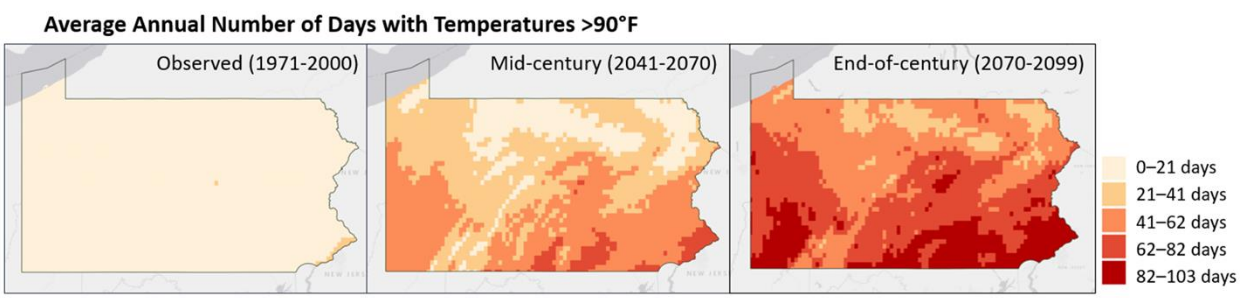
range of strategies that could be employed meet the Commonwealth's GHG reduction goals, while also increasing resilience and adapting to the risks from climate impacts.

This 2021 plan is the CAP's fifth iteration. Building on previous plans and the latest science on the impacts of climate change, it lays out strategies to help Pennsylvania meet the Governor's 2025 and 2050 emission reduction goals, while also helping to prepare for future climate change impacts, and giving added consideration to the plan's effects on public health and equity.

Climate change is already impacting Pennsylvania; worsening heat waves, increased flooding, and other impacts are affecting the state economy and public health. The 2021 Impacts Assessment, published in May 2021, summarizes expected impacts and risks over the next 30 years and beyond, such as:

- The average annual temperature statewide is expected to increase by about 6 degrees Fahrenheit. Extreme heat events will also increase: 90+-degree temperatures are expected to occur approximately 37 days per year, up from 5 days historically; such impacts will, for example, alter the growing season, increase cooling energy use, and decrease heating energy use (Figure ES-1).
- Total average rainfall will increase, coming in less frequent but heavier rain events, but 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 expected to see lower water levels, increased coastal erosion, and higher water temperatures.

Figure ES-1. Observed and projected annual days with temperatures above 90°F



Rising temperatures and heavy precipitation with inland flooding are identified in the Impacts Assessment as the two highest-risk hazards by mid-century. Increasing temperatures will have major consequences for human health and environmental justice and equity, especially in urban areas. Heavy precipitation and flooding could severely affect human health, agriculture, and built infrastructure, with those in or near floodplains at greatest risk.

Pennsylvania Greenhouse Gas Inventory, Forecast, and Reduction Efforts

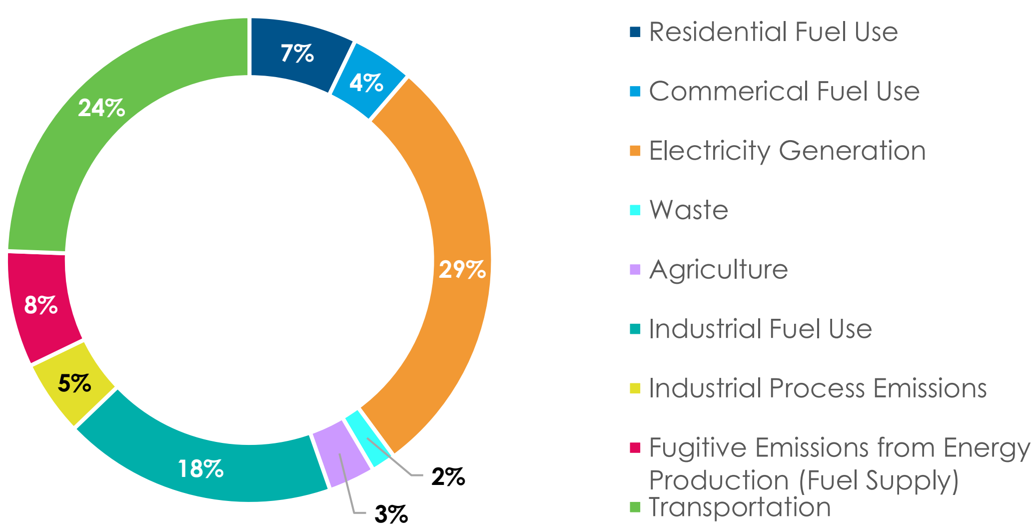
Pennsylvania's latest greenhouse gas inventory reports historical GHG emissions in the Commonwealth from 2000 to 2017. This inventory provides a baseline for tracking progress in reducing GHG emissions over time; it also forms the basis of the business as usual (BAU) emissions forecast through 2050, which is the projected emission levels without any new policy or program changes after 2020. 2017 is the most recent year for Pennsylvania's GHG inventory due to the lag in data availability from the U.S. Environmental Protection Agency (EPA). Pennsylvania is currently working on the 2018 GHG Inventory, but it was not available in time for analysis in the 2021 Impacts Assessment or CAP.

Figure ES-2 below sums up Pennsylvania's 2017 GHG emissions by major sector, totaling 263.2 million metric tons of carbon dioxide or its equivalent ($MMTCO_2e$). More than 10% of that amount is captured each year in soils or vegetation, or "sequestered," resulting in "net" emissions of 233.7 $MMTCO_2e$. 2017 net emissions are almost 20% lower than 2005 levels (289.1 $MMTCO_2e$), which puts Pennsylvania about three-quarters of the way to its 26% reduction goal by 2025.

Emissions have declined since 2005 in most sectors, with the exception of industrial and agricultural emissions. In 2017, the following sectors were the three largest sources of emissions:

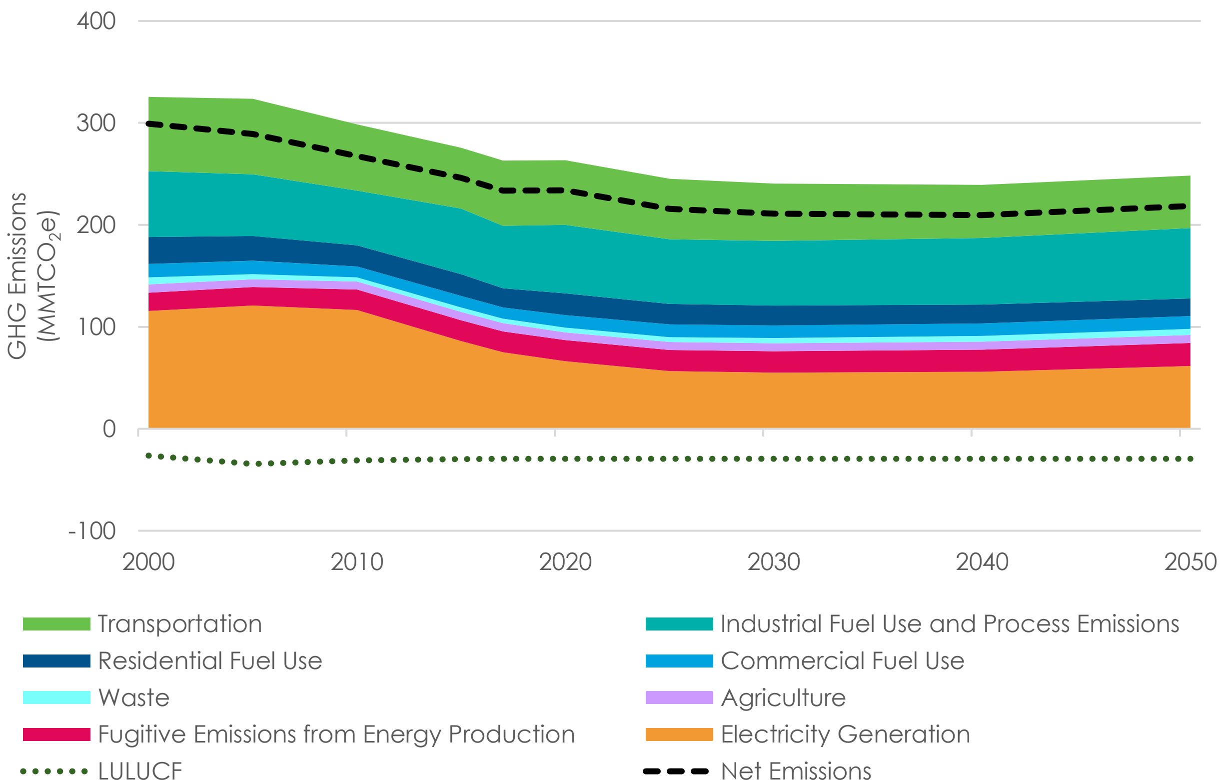
- Electricity generation (29%)
- Transportation (24%)
- Industrial fuel use (18%)

Figure ES-2. Pennsylvania 2017 GHG emissions by sector



Looking forward, Pennsylvania's BAU scenario projects a baseline of GHG emissions through 2050, assuming that current policies and programs, or those significantly underway in development, are implemented, and thus serving as a benchmark for projecting the impacts of potential GHG reduction strategies. The graphic below shows BAU emissions through 2050: it projects net emissions falling by 24% from 2005 levels. This means that while current policies and actions are expected to almost hit the state goal of reducing GHG emissions 26% by 2025, they fall far short of the 80% emission reductions by 2050 goal. The rest of the required 2050 reductions can be achieved through implementing the CAP's strategies.

Figure ES-3. Business as usual net emissions by sector 2000-2050 ($MMTCO_2e$)



It is important in the context of the BAU assessment to recognize Pennsylvania's energy policies and programs, and key features of its energy economy, that shape both today's energy and environmental agenda and tomorrow's policy and program solutions. Pennsylvania is a leading energy producer and supplier, which has historically and significantly contributed to local economies and wealth. Pennsylvania's energy profile has become increasingly dynamic in recent decades, as both fossil fuel and clean energy generation have grown. These changes, however, have resulted in both challenges and opportunities for reducing GHG emissions. Additional opportunities remain for both improving resilience in Pennsylvania's energy infrastructure and deploying new and diverse energy resources to result in assured energy supply and to mitigate the impacts of climate change. The Commonwealth is the nation's second leading natural gas producer (after Texas) and the largest electricity generator in its region.[2] In 2019, there were more than 269,000 total energy and motor vehicle sector jobs in Pennsylvania; of those, more than 97,000 were clean energy jobs. [3]

Falling costs for renewable energy, and policies such as the AEPS, have boosted the role of renewable power in the energy mix. However, zero emission energy generation in Pennsylvania is heavily reliant on nuclear power; the Commonwealth is the nation's second largest nuclear power producer. To further reduce power plant emissions, DEP is currently undertaking a rulemaking process to enable Pennsylvania to join the Regional Greenhouse Gas Initiative (RGGI), an 11-state power sector carbon dioxide cap-and-trade program. Participation in RGGI, in addition to driving down emissions, could also create funding to be used in supporting further reductions in GHG emissions.

Energy efficiency has also become a significant source of emissions reductions through more than 10 years of Act 129 implementation, in which the seven largest electric companies meet savings targets by reducing customers' electricity consumption. Act 129 does not cover fuel oil or natural gas use, and fuel oil use is relatively high in rural areas. Cleaner fuels like ethanol and biofuels are mostly used in the transportation sector. To further address transportation fuel emissions, Pennsylvania has been participating in discussions which have helped to develop the Transportation Climate Initiative (TCI), which aims to reduce emissions from the transportation sector. While PA has not committed at this time to joining the TCI Program (TCI-P), which would require fuel suppliers to purchase "allowances" for the GHG emissions resulting from the combustion of fuels sold in participating jurisdictions using cap-and-trade mechanisms, TCI-P is designed such that Pennsylvania may consider participation in the future.

PA Policies Informing the BAU Scenario

- **Act 129.** Act 129 requires PA's seven largest electric distribution companies (EDCs) to reduce customer energy use.
- **Alternative Energy Portfolio Standard.** AEPS sets targets for renewable electricity supplied by PA's EDCs. AEPS 2020 rules are projected to remain constant through 2050.
- **Regional Greenhouse Gas Initiative.** By joining RGGI, Pennsylvania would commit to reducing powerplant emissions along with 11 other states. RGGI 2020 rules are projected to remain in place through 2050. RGGI will not take effect in Pennsylvania until 2022.
- **Hydrofluorocarbon (HFC) Phaseout.** HFC chemicals are found in air conditioning refrigerants. PA will phase out HFCs in accordance with the Federal AIM Act.

---

[2] U.S. Energy Information Administration (2020). Pennsylvania State Energy Profile. https://www.eia.gov/state/print.php?sid=PA

[3] PA Department of Environmental Protection (2020). Workforce Development. https://www.dep.pa.gov/Business/Energy/OfficeofPollutionPrevention/EnergyEfficiency_Environment_and_EconomicsInitiative/Pages/Workforce-Development.aspx

Pennsylvania has undertaken numerous energy and environmental programs and policies since the early 1990s. Some of the most notable and ongoing examples include:

- Act 213: Alternative Energy Portfolio Standards (AEPS) (2004),
- Act 70: Pennsylvania Climate Change Act (2008),
- Act 129: Energy Efficiency and Conservation Program (2008),
- Act 30: Commercial Property Assessed Clean Energy Program (C-PACE) (2017),
- Act 40: Solar Renewable Energy Credits (2017),
- The Medium- and Heavy-Duty Zero Emission Vehicle MOU,
- Governor's Executive Order 2019-01, which set GHG reduction goals for Pennsylvania and sustainability goals for Commonwealth agencies (2019), and
- Governor's Executive Order 2019-07, which enabled Pennsylvania to join RGGI (2019).

These and other efforts have evolved to support a broader transition to a cleaner and more resilient energy future, encompassing a wide range of organizational, regulatory, and program initiatives. Examples include:

- Regulating volatile organic compounds (VOCs), which reduces co-pollutants like methane emissions from natural gas,
- Planning for climate adaptation,
- Incentives for clean vehicles, and
- Clean energy financing.

The list of efforts underway in state and local governments and the private sector grows ever longer. For more information on these and other ongoing efforts, visit DEP's website: https://www.dep.pa.gov.

Opportunities to Significantly Reduce GHG Emissions in Pennsylvania

DEP worked with the CCAC and other agencies, in addition to gathering public input via a public survey and best-practice information from around the country, to identify, prioritize, and model the impacts of a wide range of strategies for reducing GHG emissions across Pennsylvania's buildings, industry, transportation, power, fuels, agricultural, other land use, and waste sectors. These are summarized in Table ES-1. Considerable deliberation went into identifying, prioritizing, describing, and modeling these strategies; the methods and process for those efforts are described in the body of the plan. Strategies with quantified GHG reductions, costs, and benefits are assigned A-R for ease of reference throughout this plan.

Table ES-1. 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	A. Support energy efficiency through building codes	Near-term	Yes
	B. Improve residential and commercial energy efficiency (electricity)	Near term	Yes
	C. Improve residential and commercial energy efficiency (gas)	Near term	Yes
	D. Incentivize building electrification	Midterm	Yes
	Introduce state appliance efficiency standards	Midterm	No
	E. Increase distributed on-site solar	Near term	Yes
	Take actions to promote and advance C-PACE financing and other tools for Net Zero Buildings and high-performance buildings	Near term	No
Transportation	F. Increase fuel efficiency of all light duty vehicles and reduce vehicle miles traveled for single occupancy vehicles	Midterm	Yes
	G. Implement the multi-state medium-and heavy-duty zero-emission vehicle memorandum of understanding	Long term	Yes
	H. Increase adoption of light-duty electric vehicles	Midterm	Yes
	I. Implement a Low Carbon Fuel Standard	Midterm	Yes
Industry	J. Increase industrial energy efficiency and fuel switching	Near term	Yes
Fuel Supply	K. Increase production and use of biogas/renewable gas	Midterm	Yes
	L. Incentivize and increase use of distributed Combined Heat and Power	Near term	Yes
	M. Reduce methane emissions across oil and natural gas systems	Midterm	Yes
Electricity Generation	N. Maintain nuclear generation at current levels	Near term	Yes
	O. Create a carbon emissions free grid	Long term	Yes
Agriculture	P. Use programs, tools, and incentives to increase energy efficiency for agriculture	Near term	Yes
	Q. Provide trainings and tools to implement agricultural best practices	Midterm	Yes
LULUCF	R. Increase land and forest management for natural sequestration	Midterm	Yes
Waste	Reduce food waste	Near term	No
	Reduce waste generated by citizens and businesses and expand beneficial use of waste	Near term	No

Highlights of Key Results

The following are highlights of key results of modeled GHG reduction strategies, which include GHG emission reductions and different measures of cost-effectiveness (i.e., costs, jobs, economic growth). Health and social benefits were also analyzed outside of modeling efforts, and are discussed in the body of the plan.

Pennsylvania will likely exceed the 26% GHG emission reduction target by 2025, if all the modeled strategies are implemented and expected impacts are realized. The success of strategies in the fuel supply and industrial sectors will be especially important from now to 2025.

Reaching the 80% reduction target by 2050 will require successful implementation of all recommended strategies. Electricity generation strategies show the greatest potential for reductions through 2050, followed by the transportation, industrial, and buildings sectors. The electricity sector sheds its GHG emissions by producing almost all of its power from nuclear and renewable sources, which is one potential scenario for a future clean grid.

The strategies outlined in the CAP create jobs through cost-effective strategies while sustaining economic growth. Insights from the modeling results show that the CAP strategies:

- **Create over one million job-years[4] by 2050**, with an annual average close to 42,000 supported jobs per year, an increase of about 0.5% per year on average.
- **Result in little effect on economic growth while promoting a more environmentally sustainable future for Pennsylvania**. The average annual gross state product (GSP) decreases marginally by 0.01% overall, but rises in later years with an equivalent GSP increase of about 0.1% annually by 2050. Thus, the Pennsylvania economy continues to grow robustly with CAP strategies in place and the changes in GSP being on the margin, without affecting the overall growth path of the state economy. Similar patterns are expected for personal income changes as well, with slight annual decreases in early years, followed by slight annual increases in later years. The Commonwealth economy continues to grow with these strategies in place, but at a slightly slower rate than without any action to reduce emissions to mitigate the impacts of climate change.
- **Are cost-effective.** Taken together, the CAP strategies cost less per ton of GHG emissions reduced than the cost of inaction**.** Most strategies also create co-benefits such as improved air and water quality, improved health outcomes, increased energy security, and improved equity and environmental justice outcomes.

It is also important to note that these emission reduction strategies will likely reduce need for adaptation investments, and those benefits are not calculated in the CAP modeling process. In

[4] A job-year is defined as one year of work for one person. For example, a new construction job that lasts five years is five job-years.

addition, some of the CAP's emission reduction strategies provide adaptation co-benefits, and vice versa; while not modeled quantitatively, the body of the plan identifies these synergies.

GHG Reduction Modeling Results Highlights

The CAP modeling process showed that Pennsylvania's 2025 and 2050 GHG reduction targets can be met by implementing strategies across all sectors. The "wedge graph" (Figure ES-4) below illustrates a possible pathway to 80% reductions by 2050. The 2025 reduction target could be exceeded through successful implementation of the modeled strategies; beyond that point, sustained impacts are needed from all strategies for the next 25 years. **Figure ES-5** shows annual reductions by sector compared to the BAU for select years.

Figure ES-4. GHG reductions by strategy, through 2050 ($MMTCO_2e$)

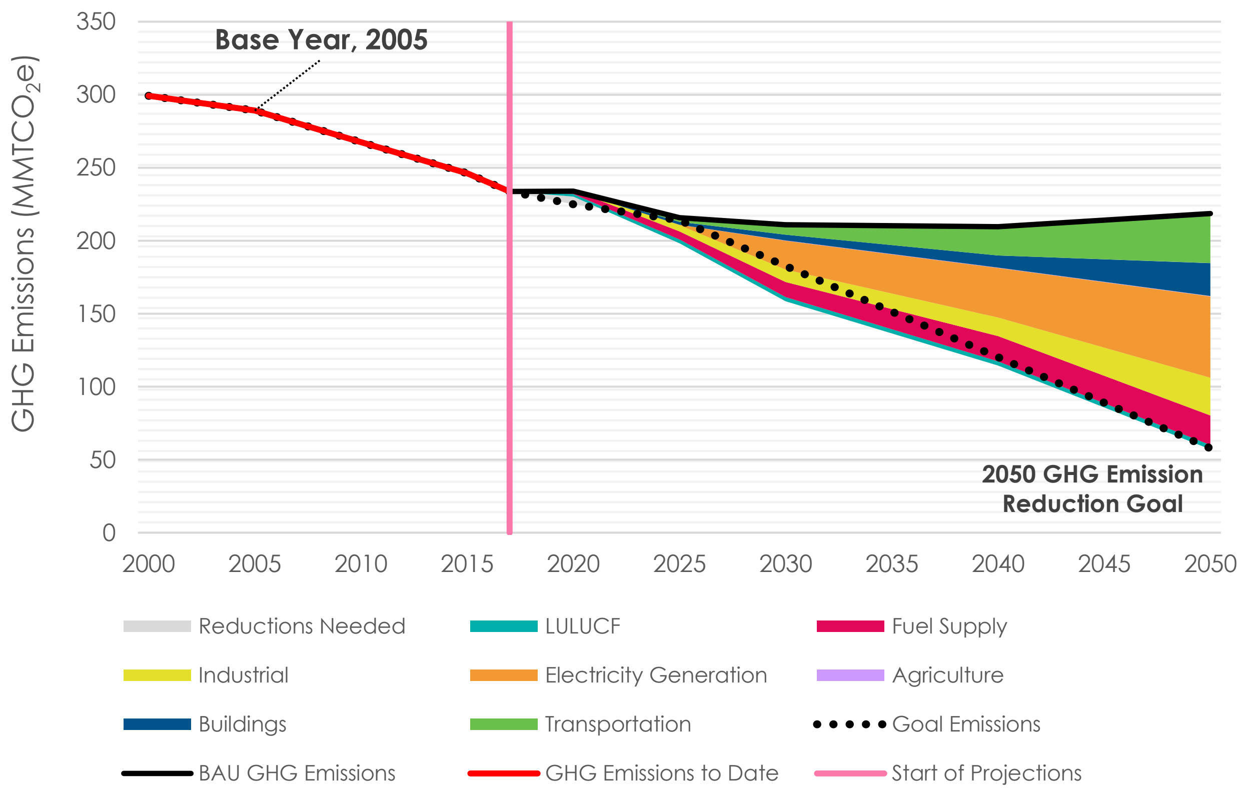
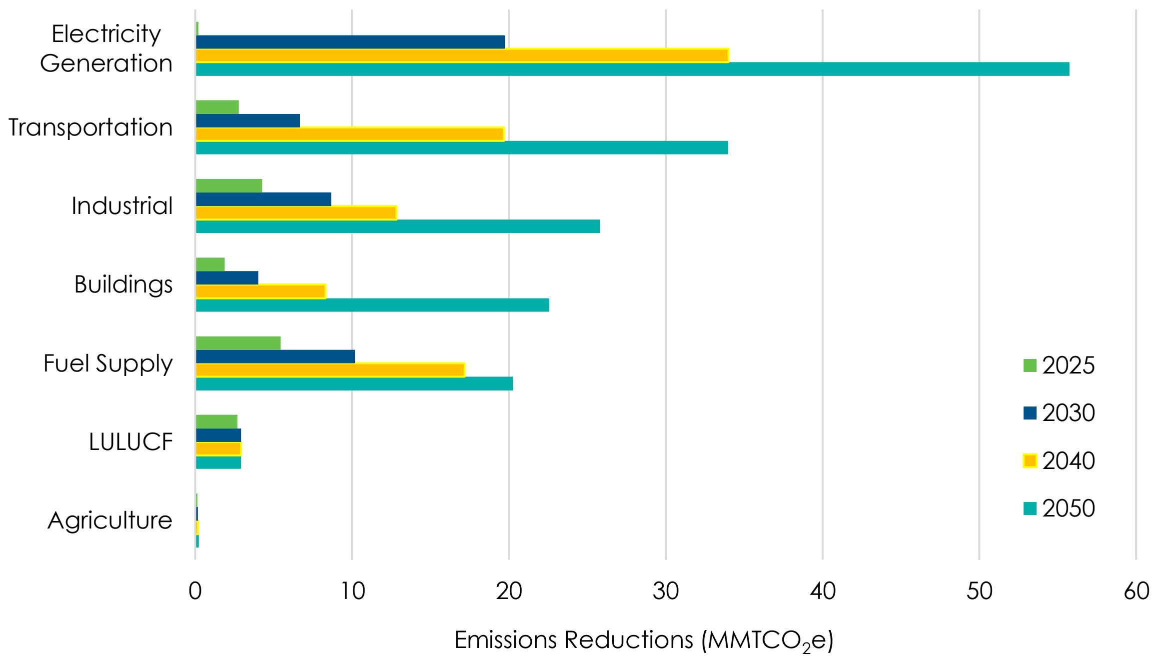


Figure ES-5. GHG reductions by sector for select years, compared to business as usual



The CAP provides extensive additional details on the modeling process, the strategies that were modeled, the modeling results, as well as detailed descriptions of each strategy. It also explores implementation considerations for these strategies, such as cost, political, and environmental justice considerations, and examines enabling technologies that will likely be needed to facilitate full realization of strategy impacts.

Opportunities to Adapt to the Impacts of Climate Change

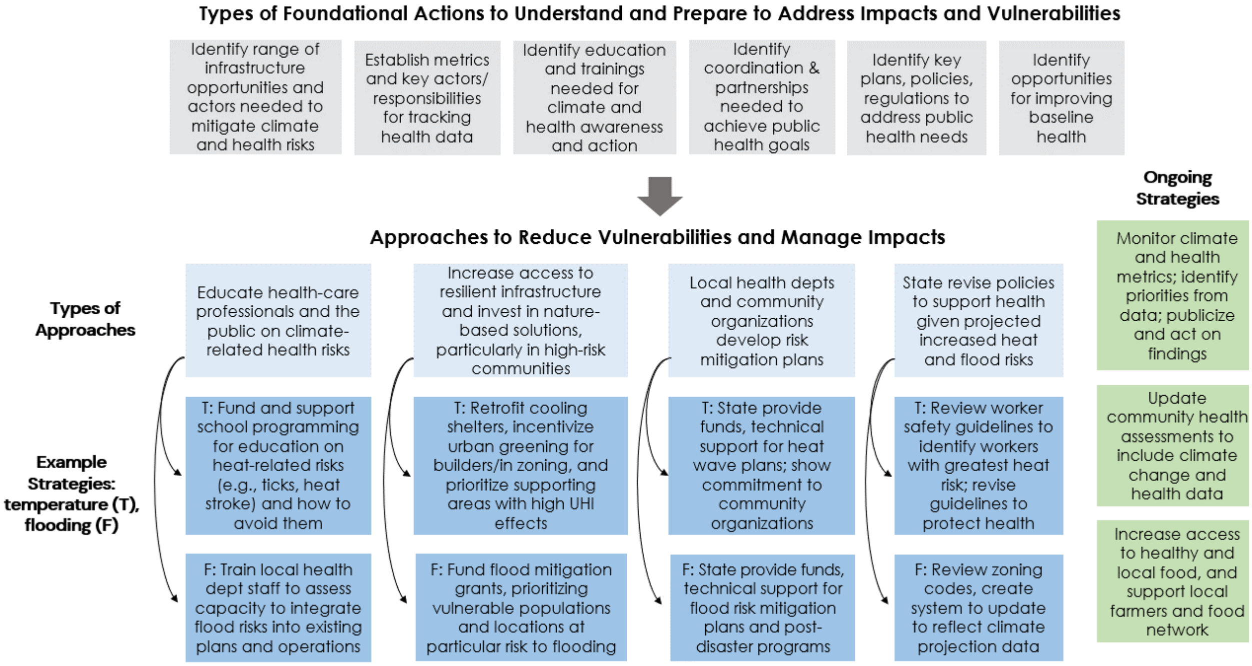
Climate risks and related impacts in Pennsylvania could be severe, potentially causing increased infrastructure disruptions, higher risks to public health, economic impacts, and other changes, unless actions are taken by the Commonwealth to avoid and reduce the consequences of climate change. Taking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

As a result of the 2021 Impacts Assessment, seven priority areas were identified for climate adaptation:

- Increasing heat and flooding on health
- Increasing heat and flooding on overburdened and vulnerable populations
- Increasing average temperatures on forests, ecosystems, and wildlife
- Warmer and wetter climate on agriculture
- Increasing average temperatures on recreation and tourism
- Flooding on built infrastructure
- Landslides on built infrastructure.

The CAP describes a wide range of strategies to help Pennsylvanians adapt to these priority unavoidable impacts of climate change, even as the GHG reduction strategies work to reduce these impacts. Figure ES-6 below illustrates the CAP's approach to adaptation for reducing impacts of heat and flooding on health (one of the seven priority areas); Section 4 provides greater detail across a wide range of impacts and adaptation strategies.

Figure ES-6. Adaptation strategy pathway to reduce public health impacts from heat and flooding



This diagram provides illustrative examples of the primary types of strategies but does not capture the full universe of possible strategies that could be deployed.

Pennsylvania can use a combination of strategies to manage climate risks and can plan and implement strategies over time as conditions and information change. This approach is referred to as "adaptive management" (see Section 4). The Commonwealth can draw on strategies in this CAP as well as other resources.

Below are two examples (Figure ES-7, Figure ES-8) that visualize how adaptive management could be used to manage flood and heat risks in Pennsylvania. They show how new information about future climate risks (e.g., the 2021 Impacts Assessment) and the occurrence of events that will become more frequent (e.g., severe flooding) can guide the Commonwealth in selecting and implementing adaptation strategies. In particular, they illustrate how extreme events—such as a flood that causes devastating infrastructure damage, or a heat wave with a heightened death toll—harm people and places and thereby motivate society to both reconsider what risks are acceptable and take action to reduce risks by implementing additional adaptation strategies.

Figure ES-7. Example adaptive management approaches to flood risk

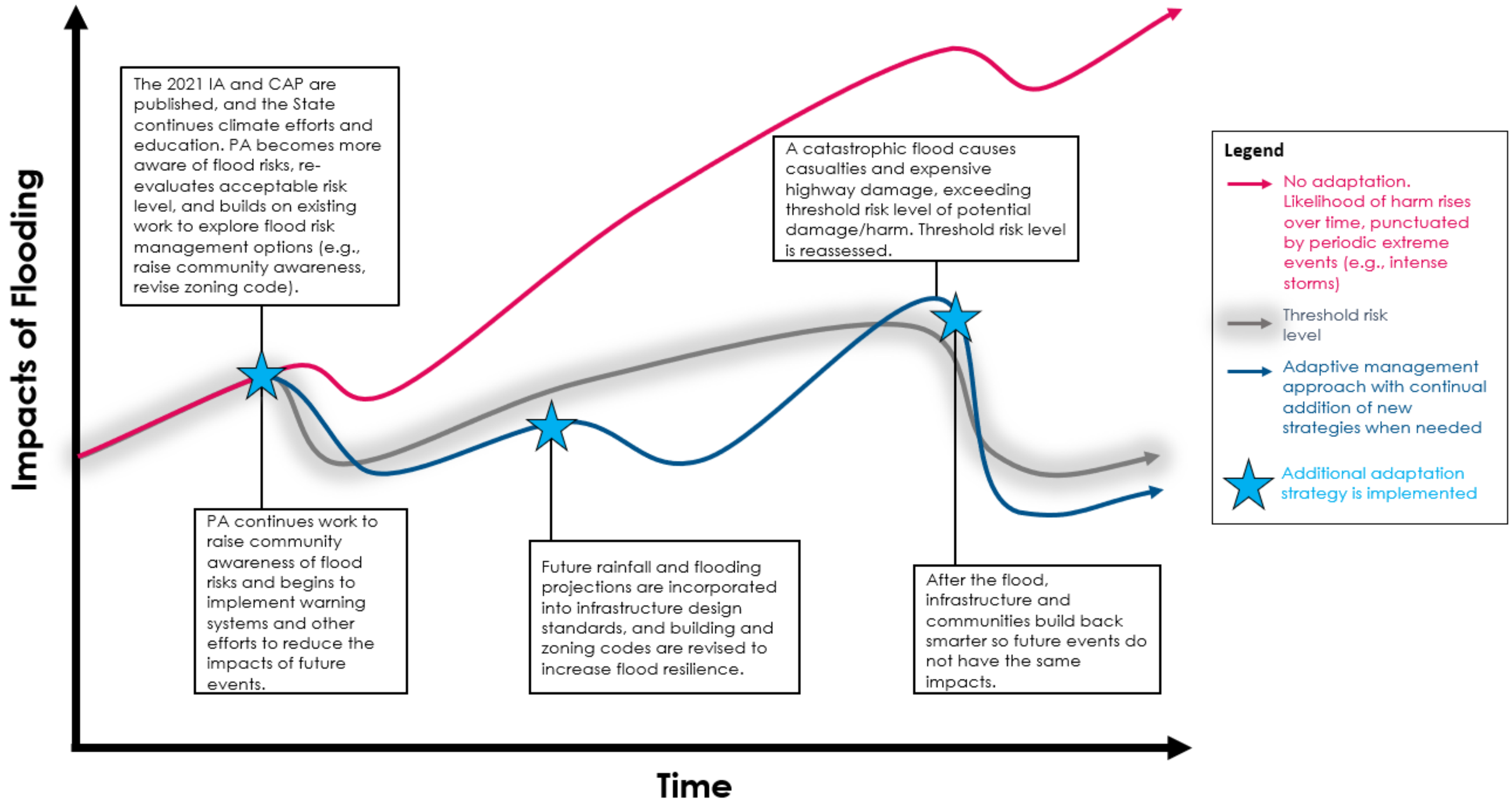
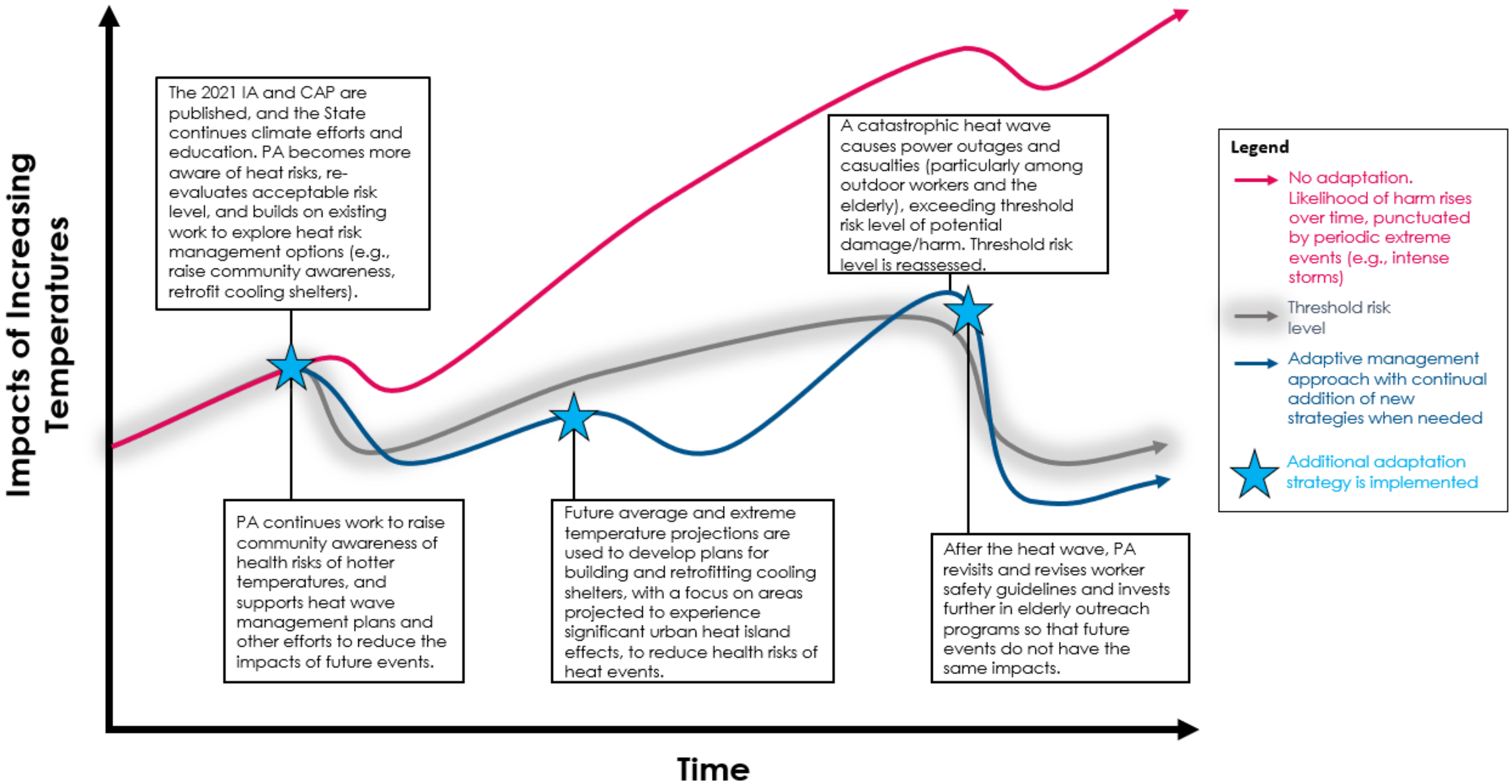


Figure ES-8. Example adaptive management approaches to heat risk



1 INTRODUCTION

How to Use This Climate Action Plan

This 2021 Climate Action Plan was developed primarily to serve as a guide for leaders and decision makers to set priorities, develop policies and programs, and take data-informed action to reduce GHG emissions and adapt to a changing climate. This plan is not an exhaustive list of all strategies that can be implemented to mitigate climate change, but presents a suite of GHG reduction strategies selected by DEP with advisement by the Climate Change Advisory Committee to meet Pennsylvania's GHG reduction goals. This plan also provides strategies for all Pennsylvanians for adapting to a changing climate.

Legislative and Executive Foundations of the Climate Action Plan

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 GHG emissions, to develop a voluntary GHG registry, and to develop a climate action plan (CAP) and impacts assessment and update them every three years. Act 70 also established the Climate Change Advisory Committee (CCAC) to advise DEP during the development of the Impacts Assessment and CAP. 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
- Develop a Climate Action Plan and Impacts Assessment
- Establish a Climate Change Advisory Committee

Executive Order 2019-01

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

In 2019, before the release of the fourth 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 reestablished the GreenGov Council to encourage the state to incorporate environmentally sustainable practices into the Commonwealth's policy and planning decisions. The third paragraph of the EO also states:

> *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." Net emissions are equal to total (i.e., "gross") emissions minus emissions captured or sequestered (e.g., by forestry and land use). These goals are in line with the goals of the Paris Agreement.[5]

This 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 GHG reductions goals of the EO. This 2021 plan also recognizes and maps out flexible strategies and pathways for adapting to the impacts of climate change in Pennsylvania, building directly on the 2021 Pennsylvania Climate Impacts Assessment.

Pennsylvania's Evolving Energy and Climate Efforts

Since the initial CAP and Impacts Assessment 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 important because it allows DEP to map out how climate-relevant policies and programs can continue to evolve, and to determine how potential new policies and programs can lead to further GHG reductions, increased resiliency, and reduced risk from climate impacts, to the benefit of all Pennsylvanians. Previous 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) and developing the Pennsylvania Commercial Property Assessed Clean Energy (C-PACE) Program[6] and ongoing industrial energy assessments.[7]

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, new and expanded strategies to

---

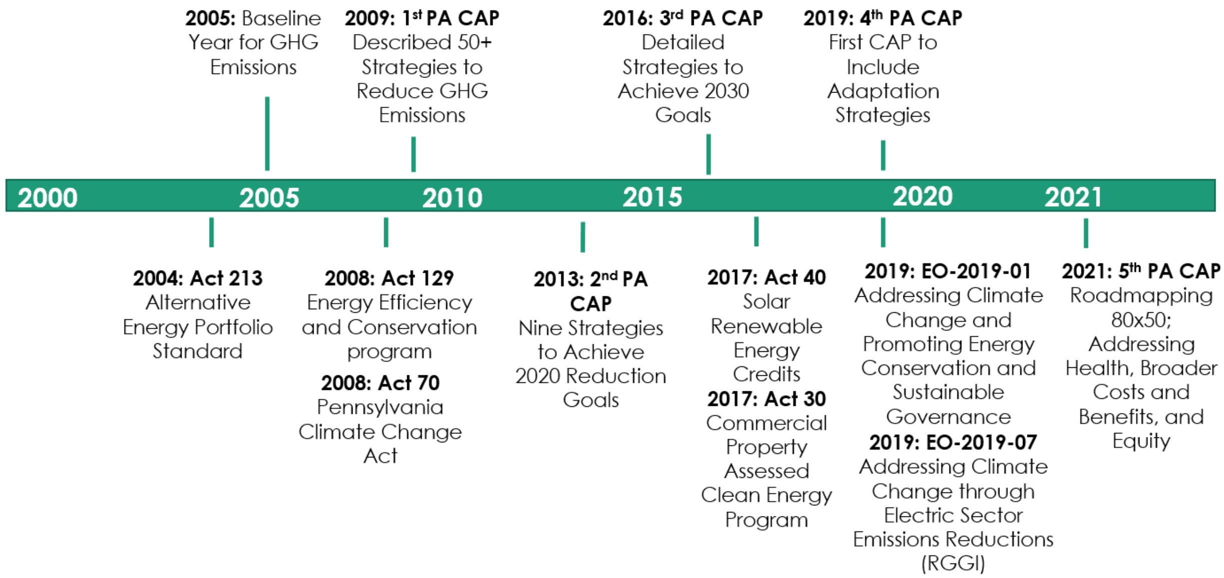
[5] The stated goal of the Paris Agreement is "to limit global warming to well below 2°Celsius, preferably to 1.5°C, compared to pre-industrial levels." Details on the Paris Agreement can be found on the UNFCCC website: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement#:~:text=The%20Paris%20Agreement's%20central%20aim,further%20to%2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

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

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

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



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.

The 2021 Pennsylvania Climate Impacts Assessment, published in May 2021, summarizes the latest expected impacts and risks from climate change in the Commonwealth. By midcentury, the following climatic changes (compared to a 1971–2000 baseline) are expected:

- 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 expected to undergo significant changes in water level, coastal erosion, and water temperature.

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

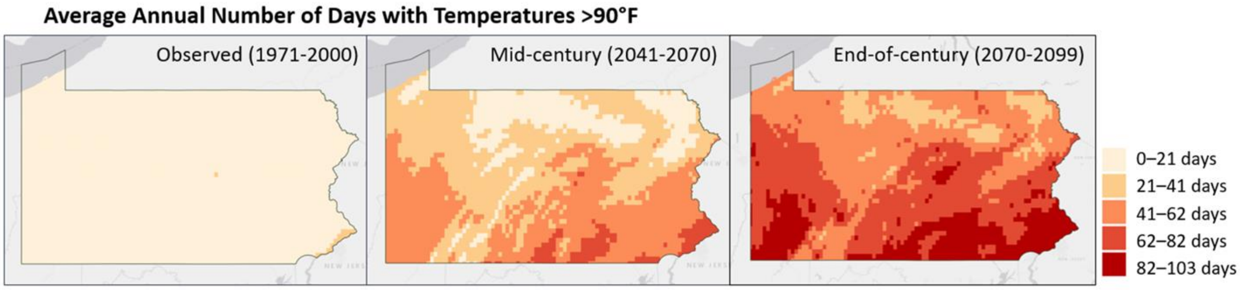
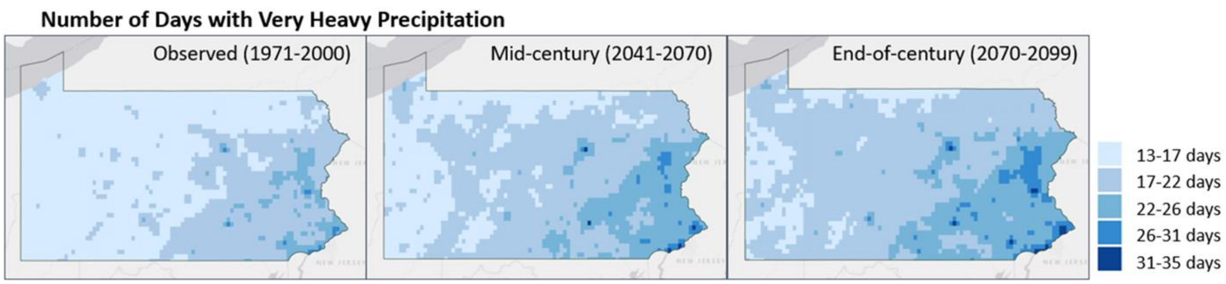


Figure 3. Observed and projected annual days with "very heavy" precipitation



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

As Pennsylvania works to reduce its climate risks, adapt to climate change, and increase its resilience, it must address any inequitable impacts and ensure that adaptation efforts do not inadvertently exacerbate inequities. Instead, adaptation actions should reduce impacts on vulnerable populations. The 2021 Impacts 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.[8]
- 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.

The Impacts Assessment found that increasing average temperatures and heavy precipitation and inland flooding are the two highest-risk hazards by midcentury. Both hazards could affect the entire state and all sectors (Figures 2 and 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.

Adaptation vs. Resilience

Adapting to climate change and increasing resilience to climate risks often go hand in hand. However, the terms have different central meanings, and their definitions may vary by context and the actor using them. The CAP has adapted definitions from the National Climate Assessment (NCA), an industry standard for climate risk assessment and adaptation planning in the U.S.

Adaptation is the process of adjusting to new or changing climate conditions to reduce or avoid negative impacts to valued assets and take advantage of emerging opportunities.

Resilience is the capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from disturbances, while retaining the basic functions of the system.

For example, Pennsylvania may *adapt* to changing climate conditions by tracking metrics for climate and health and using them alongside climate projections (e.g., future temperature data) to inform public health planning, which will in turn increase the *resilience* of Pennsylvanians to future extreme heat events.

Effects of COVID-19

The COVID-19 pandemic emerged in late 2019 and shut down vast swathes of Pennsylvania, the United States, and the world, off and on throughout 2020 and into 2021. It created extreme conditions that affected all aspects of society, the economy, and the environment from which we are beginning to recover as of the date of this plan. The pandemic caused businesses to shut down (temporarily and permanently), cost people their lives and livelihoods, restricted travel and cultural events, and burdened the healthcare system. For example, 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, Pennsylvania's tax revenue was

---

[8] This includes energy efficiency, ratemaking that reduces or does not impose rate increases on low income customers, and electrification schemes that do not shift multifamily energy bills from landlords to tenants, for example.

nearly $3.2 billion less than expected, a budget gap of about 9%.[9] For clean energy jobs specifically, by December 2020, industry jobs had declined 12% from the previous year, and only 30% of the jobs lost in the early months were recovered. Experts estimate that it may take years for the sector to fully recover.[10] The impacts to healthcare were particularly egregious as COVID patients strained hospital resources and priorities. Hospitals initially lacked resources such as personal protective equipment and respirators and faced budget shortfalls, threatening the long-term viability of some hospitals.[11] As of June 2021, there were over 1.2 million total cases and over 27,000 deaths attributed to COVID-19 in Pennsylvania.[12]

Although these and other effects of COVID-19 are severe and ongoing, the CAP, particularly the GHG modeling, does not account for the effects of COVID-19. This is because with just a year of data available, analysis of the short-and long-term effects of COVID-19 on energy use and emission related trends is highly uncertain, especially as more people are vaccinated and society returns to normal. The 2021 dataset from the Energy Information Administration's Annual Energy Outlook (AEO), released after the emissions projections were completed for the 2021 CAP, projects that the effects of COVID-19 will be felt mainly in the short term.[13] Following a sharp decline in energy consumption and associated emissions, a recovery to pre-pandemic levels is expected in the next four to five years. The long-term energy trends are quite similar between the 2020[14] and 2021 AEO projections, indicating that the energy sector will not experience significant long-term impacts of COVID-19. Because this CAP focuses mainly on emissions reductions in the long-term (i.e., through 2050), the short-term impacts of COVID-19 are not included in the modeling. Additionally, the full impacts of the pandemic and recovery efforts will take years to fully materialize in available data. Therefore, the effects of COVID-19 will be incorporated into the 2024 CAP when the resultant data are more certain and robust.

CAP Development Process

The development of this CAP was informed by the current and anticipated climate risks Pennsylvania faces and builds on the historical and current climate work of DEP and others. DEP led the development of the Impacts Assessment and this CAP—two related climate assessment and planning efforts that were developed concurrently. The ICF team, including its

---

[9] Political Economy Research Institute (PERI). 2021. *Impacts of the Reimagine Appalachia and Clean Energy Transition Programs for Pennsylvania.* https://reimagineappalachia.org/wp-content/uploads/2021/01/Pollin-et-al-PA-Final-Report-1-22-21.pdf.

[10] Environmental Entrepreneurs (E2). 2020. Clean Jobs Pennsylvania: Pennsylvania's Key to Economic Recovery. https://e2.org/wp-content/uploads/2020/09/Clean-Jobs-Pennsylvania-2020.pdf.

[11] The Hospital and Healthsystem Association of Pennsylvania. 2020. "Report: Analysis of the Impacts of COVID-19 on Pennsylvania Hospitals." https://www.haponline.org/Resource-Center?resourceid=475.

[12] Pennsylvania Department of Health. 2021. "COVID-19 Data for Pennsylvania." https://www.health.pa.gov/topics/disease/coronavirus/Pages/Cases.aspx#.

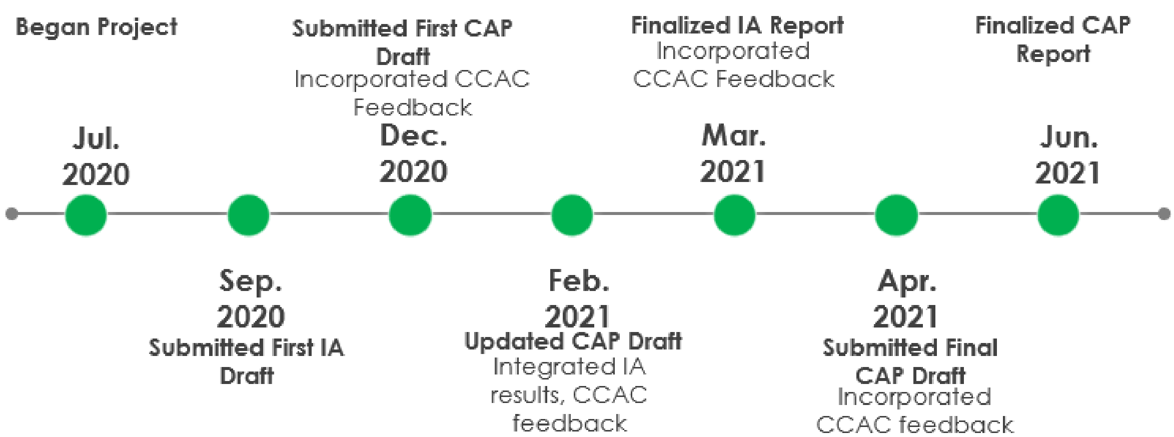
[13] U.S. Energy Information Administration. Annual Energy Outlook. 2021. https://www.eia.gov/outlooks/aeo/.

[14] U.S. Energy Information Administration. Annual Energy Outlook. 2020. https://www.eia.gov/outlooks/aeo/pdf/AEO2020%20Full%20Report.pdf

partners at Pennsylvania State University (Penn State) 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 plan. Additionally, DEP's Energy Programs Office engaged other DEP offices and state agencies throughout the planning process, including the DEP Office of Environmental Justice, the DEP Bureau of Air Quality, and the Department of Conservation and Natural Resources. DEP also engaged in public outreach through surveys, open to all Pennsylvanians, to gather information and feedback for this plan. Finally, throughout the process, DEP shared updates with and sought feedback from the 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 the Impacts Assessment and the CAP.

Work on the Climate Action Plan began in July 2020 and initially focused on assessing climate impacts through the development of the Impacts Assessment. The Impacts Assessment uses a risk-based approach to assess the impacts of climate change, which feeds into the adaptation strategies identified in this CAP. Figure 4 provides an overview of the Impacts Assessment and CAP development process timeline.

Figure 4. CAP process timeline



What this Plan Provides

The purpose of this plan is to 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.

- Section 2 describes Pennsylvania's current GHG emissions profile, the results of the business-as-usual projection, and the ongoing climate efforts.
- Section 3 outlines the approach used to identify and select GHG reduction strategies and provides a detailed description of each selected strategy and select enabling technologies.
- Section 4 summarizes the priority climate risks and impacts, as well as opportunities to adapt to those impacts.
- Section 5 details challenges and opportunities of climate action, implementation principles, and key steps and stakeholders necessary to implement the CAP.

- Appendix A provides a glossary of key terms and a list of acronyms.
- Appendix B describes the methodology used to develop the analyses in this plan.
- Appendix C provides examples of adaptation strategies in addition those described in Section 4.
- Appendix D contains letters submitted by CCAC appointees identifying "areas of agreement and disagreement" to fulfill the requirement of Act 70.

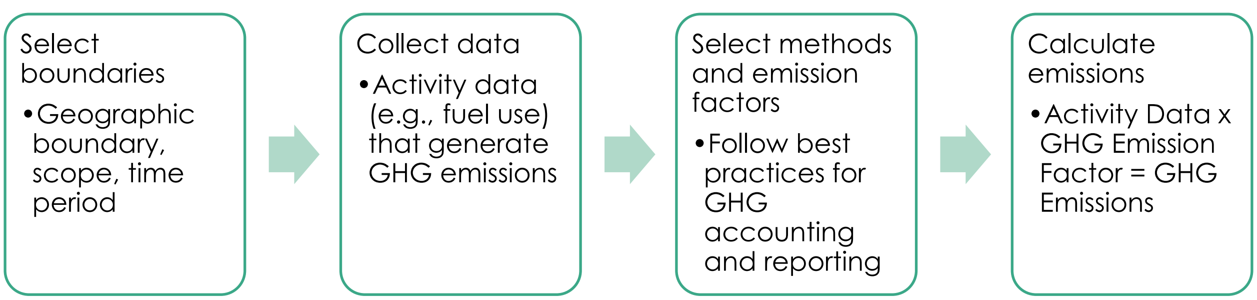
2 PENNSYLVANIA'S GREENHOUSE GAS INVENTORY, FORECAST, AND REDUCTION EFFORTS

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

Current GHG Emissions

The GHG inventory process, summarized in Figure 5, is consistent over time so that inventories can be compared as new inventories are developed. In 2020, DEP developed Pennsylvania's most recent GHG inventory for 2017 emissions by using the EPA's State Inventory Tool (SIT), which follows a standard process for generating state-level emission estimates. The SIT was used to calculate GHG emission estimates for intervals from 2000 through 2017. 2017 is the most recent year for Pennsylvania's GHG Inventory due to the lag in data availability from the EPA. Pennsylvania is currently working on the 2018 GHG Inventory, but it was not available in time for analysis in the 2021 Impacts Assessment or CAP.

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 sink).

Figure 6 shows a breakdown of 2017 GHG emissions in Pennsylvania by sector. Figure 7 provides a summary of historical gross and net GHG emissions in Pennsyvlania by sector. GHG emissions are measured in million metric tons of carbon dioxide equivalent (MMTCO_2e). The Pennsylvania GHG Inventory[15] and the Inventory of U.S. Greenhouse Gas Emissions and Sinks annual report[16] provide more granular emissions data disaggregated by each type of emission.

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.

Total statewide gross GHG emissions in 2017 were 263.2 MMTCO_2e. Gross emissions do not include carbon sequestered by the land use, land-use change, and forestry (LULUCF) sector, which sequestered 29.5 MMT CO_2e in 2017. The additional carbon sequestration from LULUCF resulted in net GHG emissions of 233.7 MMTCO_2e, which was 19.2% lower than 2005 levels (289.1 MMTCO_2e). These emissions are about three-quarters of the way to meeting Pennsylania's 2025 goal of reducing GHG emissions 26% from 2005 levels.

Emissions have declined since 2005 in most sectors, except for industrial (fuel use and process emissions) and agricultural emissions. As of 2017, the following sectors were the three largest sources of emissions, presented in order from largest to smallest:

- Electricity generation (29%)
- Transportation (24%)
- Industrial fuel use (18%).

[15] https://www.dep.pa.gov/citizens/climate/Pages/GHG-Inventory.aspx
[16] https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

Figure 6. Pennsylvania 2017 GHG emissions by sector

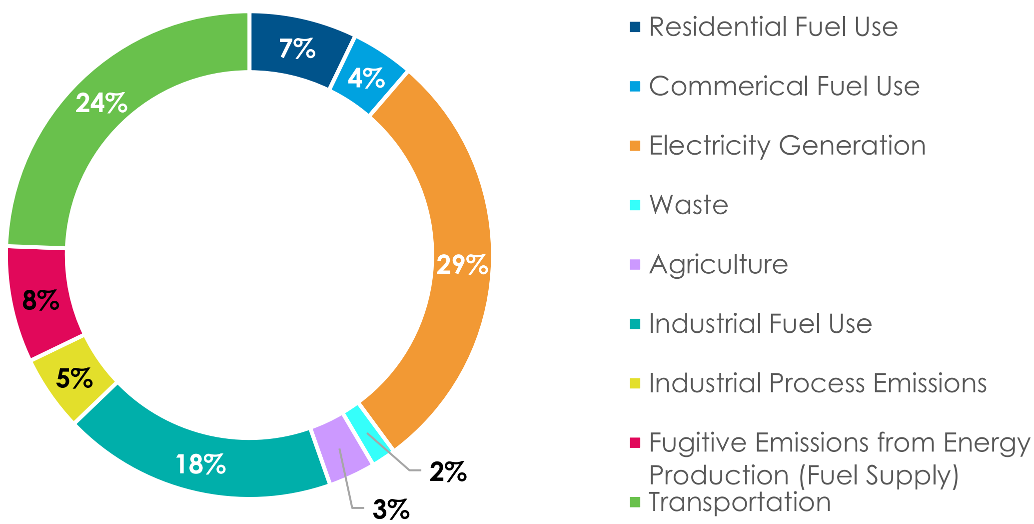
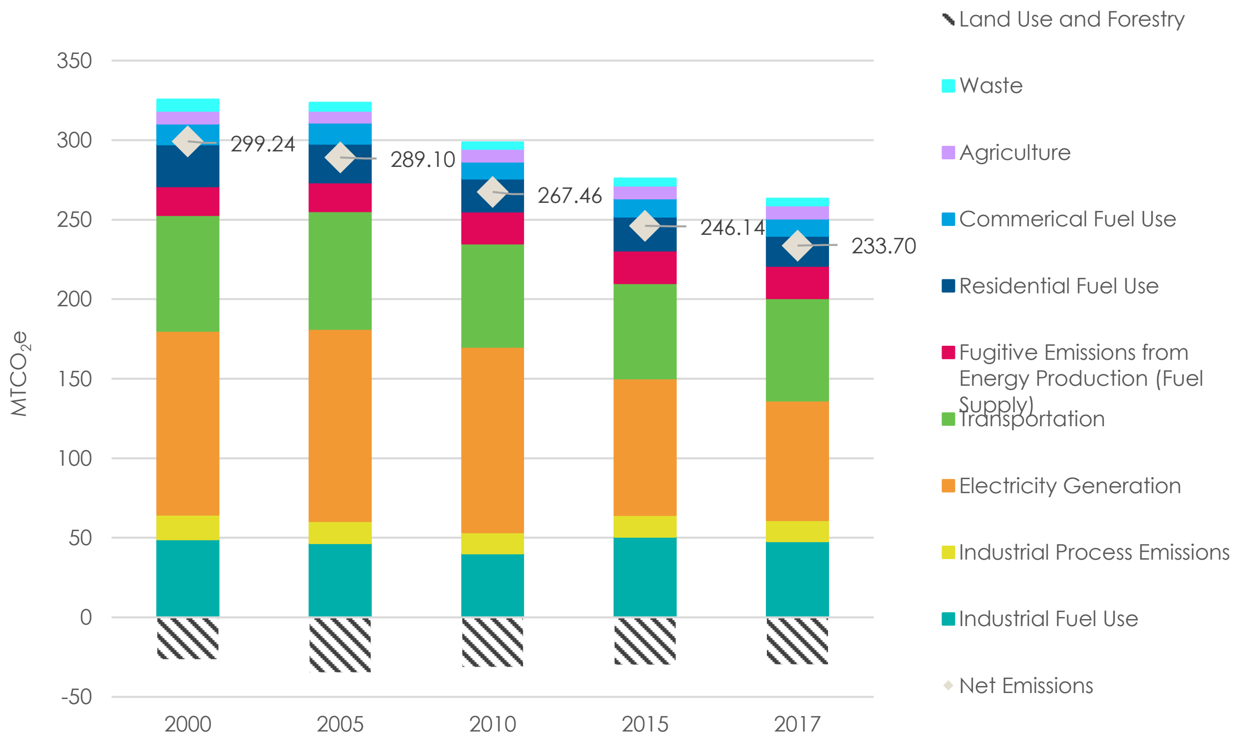


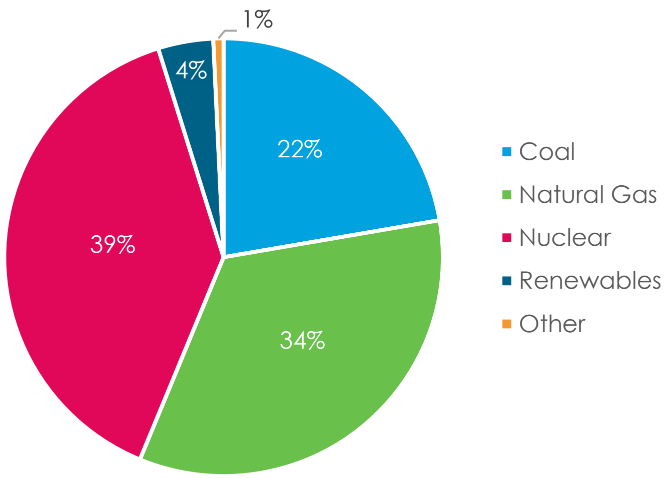
Figure 7. Pennsylvania historical net GHG emissions by sector (MMTCO₂e)



This CAP breaks out industrial emissions and fugitive emissions from energy production to translate the GHG inventory sectors to emission reduction strategies in Section 3. However, for GHG inventory purposes, both of these sources are included in the industrial sector. Electricity generation, transportation, industrial fuel use and process emissions, and fugitive energy production emissions combined 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 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. Coal-based electricity generation decreased from generating 56% of Pennsylvania's total electricity in 2005 to 22% in 2017. In 2017, nuclear power was 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. The Commonwealth's electricity generation mix has changed from year to year and will continue to change, as discussed below. As of 2020, natural gas is the largest electricity-generating source in Pennsylvania. In Figure 8, and throughout this plan, electricity generation from waste coal and traditional coal-fired generation is included in the fuel type "Coal"; the "Other" fuel type includes electricity generation from waste-to-energy and landfill gas facilities.

Figure 8. Electricity generation by fuel type, 2017



Transportation: In 2017, the transportation sector emitted 64.3 $MMTCO_2e$. The majority of transportation emissions were from gasoline-powered personal vehicles. Since 2005, transportation emissions have decreased 11%, mainly because of increased fuel efficiency standards.

Industrial: Industrial emissions made up 23% of Pennsylvania's emissions in 2017 and have increased 1% above 2005 levels to 61.2 $MMTCO_2e$. The majority of industrial emissions (48.0 $MMTCO_2e$) result from the combustion of fossil fuels. Other major sources of emissions include cement manufacturing (1.8 $MMTCO_2e$), iron and steel production (3.8 $MMTCO_2e$), and the use of ozone-depleting substance (ODS) substitutes (6.0 $MMTCO_2e$), as estimated using the SIT. The industrial sector estimates from the 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 $MMTCO_2e$ in 2017, of which 10.7 $MMTCO_2e$ was emitted by coal mining, and 9.7 $MMTCO_2e$ 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. Fugitive energy emissions increased 13% since 2005 (18 $MMTCO_2e$ to 20.6 $MMTCO_2e$). At the same time, emissions from coal mining decreased and emissions from oil and gas systems increased, to the point where each accounts for about half of fugitive 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) come from 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, a likely result of the following factors:

- Fuel switching to lower emitting fuels for heating.
- Energy efficiency improvements as a result of Act 129 (which requires efficiency improvements that also impact fuel consumption, in addition to the required reductions in electricity use).
- Technology improvements over time (e.g., ENERGY STAR certified products) that have led to increased energy efficiency.

Business-as-Usual Forecast Overview

Pennsylvania's BAU scenario uses the most recent Pennsylvania GHG inventory (2017) as a starting point, and projects GHG emissions through 2050 under current GHG reduction policies and programs.[17] The BAU is a benchmark for Pennsylvania's GHG reduction planning, providing emissions estimates that can be compared against emissions estimates for selected GHG reduction strategies. Figure 9 shows BAU emissions estimates by sector from 2000 through 2050 (actual emissions for 2000–2017, projected for 2018–2050). In the BAU scenario, Pennsylvania's net emissions are projected to be 218.68 $MMTCO_2e$ in 2050, a 24% decrease from 2005 levels (289.10 $MMTCO_2e$), 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).

Under the BAU scenario, Pennsylvania will nearly achieve its 2025 reduction goal but will not come close to achieving its 2050 reduction goal of 80% from 2005 levels. Net emissions for 2025 are projected to be 215.6 $MMTCO_2e$, a 25.4% decrease from 2005 emissions (289.1 $MMTCO_2e$), which is less than 1% short of the target set in EO 2019-01. Beyond 2025, however, BAU emissions are projected to increase slightly. Net emissions in 2050, with no additional action, are

[17] For a full list of the policies and programs included in the BAU, see Appendix B.

projected to be 218.7 $MMTCO_2e$, a 24% decrease from 2005 levels. Between 2025 and 2050, net emissions are estimated to increase by 1.4%. The increase in net emissions between 2025 and 2050 is due largely to increased emissions from electricity generation and industrial fuel use emissions. Table 1 provides a summary of GHG emissions by sector, with percentage change from 2005 to 2050.

Figure 9. Business-as-usual net emissions by sector, 2000-2050 ($MMTCO_2e$)

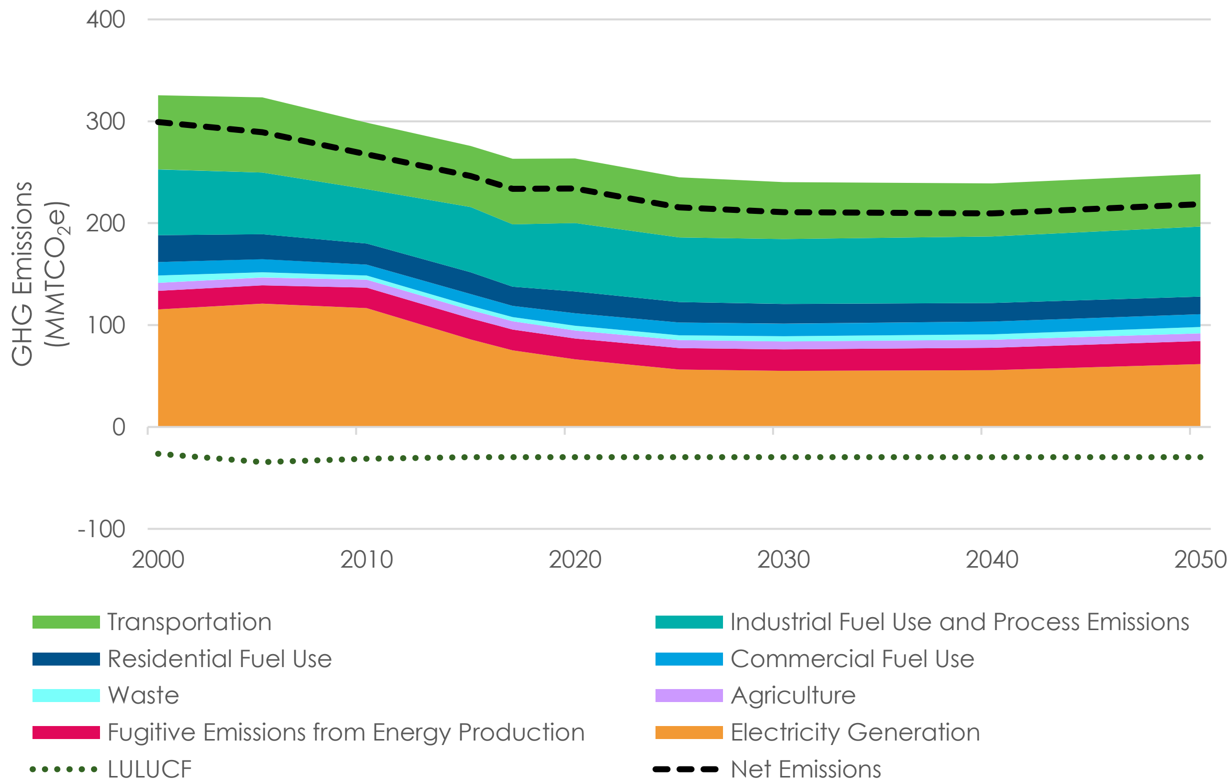


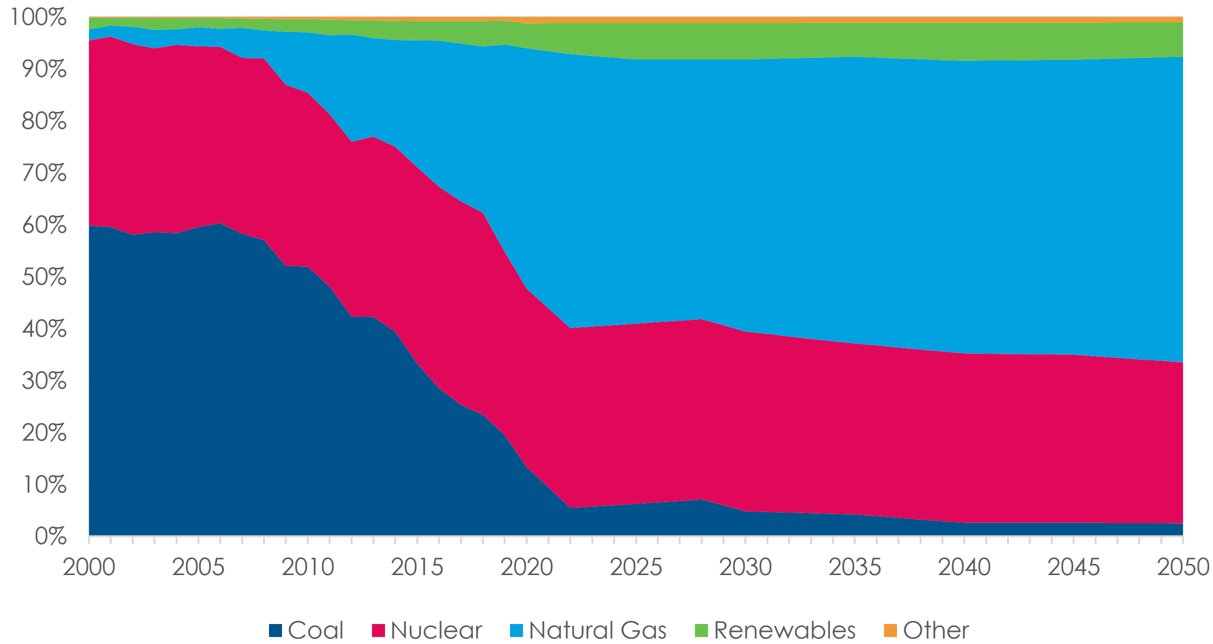
Table 1. Pennsylvania emissions by sector, business-as-usual scenario ($MMTCO_2e$)

Sector	2005	2017	2025	2030	2050	% Change 2005-2050
Electricity generation	121.0	75.2	56.4	55.1	61.6	-49.1%
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 fuel use)	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	20.9	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**	**245.2**	**240.4**	**248.2**	**-23.3%**
LULUCF	(34.5)	(29.5)	(29.5)	(29.5)	(29.5)	-14.4%
Net emissions	**289.1**	**233.7**	**215.6**	**210.9**	**218.7**	**-24.4%**

Emissions from electricity generation are projected to be 61.6 $MMTCO_2e$ in 2050, a 49% decrease from 121.0 $MMTCO_2e$ in 2005. The projected decrease in statewide 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 the AEPS and RGGI. Total electricity generation associated with in-state consumption is projected to increase from 221,670 GWh in 2020 to 245,260 GWh in 2050 as a result of modest increases in electricity use from the commercial, industrial, and transportation sectors, despite efficiency improvements from Act 129.

As of 2020, natural gas has overtaken nuclear as the largest fuel source for electricity generation in Pennsylvania and continues to replace coal generation. The coal generation that remains after in the BAU in future years is a result of waste coal supported by the AEPS Tier II requirement. Under the BAU scenario, natural gas is expected to continue growing as the primary fuel source for electricity generation; by 2050, it will produce over 58% of Pennsylvania's electricity. Nuclear generation remains steady through 2050, making up roughy one-third of the state's electricity generation. In the BAU modeling nuclear capacity is indirectly supported by RGGI, whose carbon allowance prices provide uplift to nuclear facilities. Figure 10 shows the historical and projected fuel mix for electricity generated in Pennsylvania from 2000 through 2050 (BAU scenario). In Figure 10, electricity generation from waste coal is included in the fuel type "Coal" and remains in place in 2050; the "Other" fuel type category includes electricity generation from waste-to-energy and landfill gas facilities.

Figure 10. Business-as-usual electricity generation mix over time

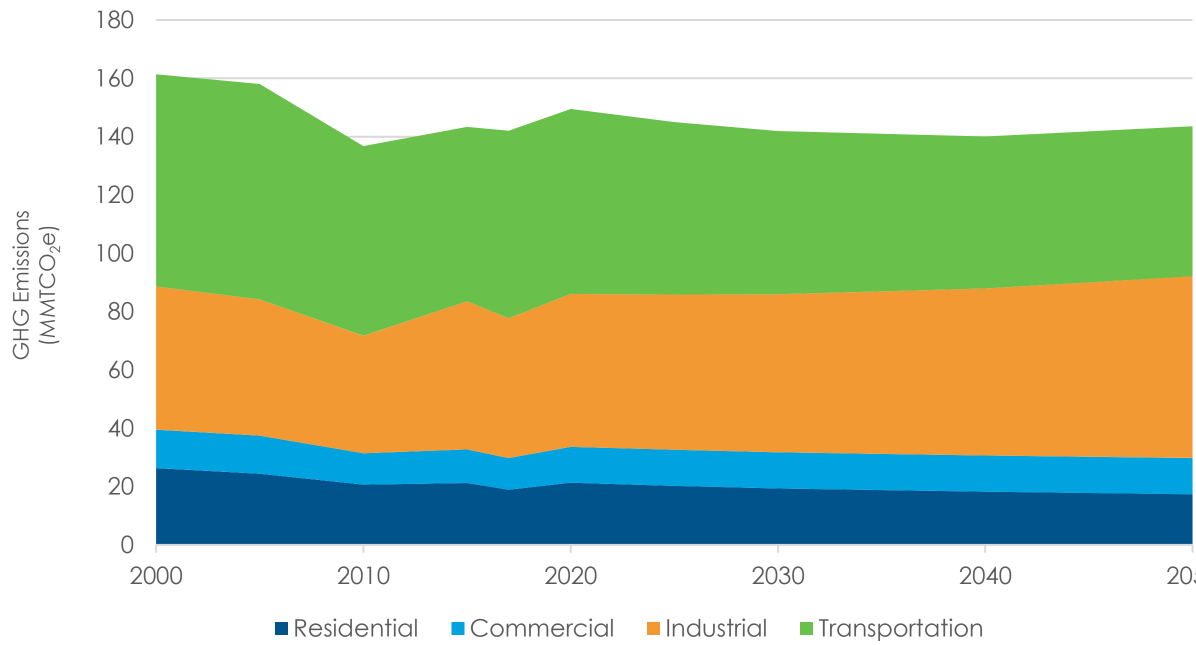


Emissions from direct fuel consumption for residential, commercial, industrial, and transportation uses, which together make up the majority of emissions in Pennsylvania (57% in 2020), are projected to decrease by 9%, from 158.1 $MMTCO_2e$ in 2005 to 143.6 $MMTCO_2e$ in 2050.

Emissions from fuel consumption for transportation and residential uses each decrease by about 30% through 2050. These reductions are likely a result of improved energy efficiency through implementation of Act 129, federal standards for electric appliances in the National Appliance Energy Conservation Act (NAECA), and advances in building energy codes; and improved efficiency of transportation fuels (e.g., motor gasoline), which will result in less fuel used to meet demand.

Industrial emissions from direct fuel consumption are projected to increase from 46.7 $MMTCO_2e$ in 2005 to 62.3 $MMTCO_2e$ in 2050. The increase is driven mainly by economic growth indicators 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, because that would result in double-counting 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 methane emissions from coal mining and natural gas and oil systems, are projected to increase from 20.6 $MMTCO_2e$ in 2020 to 22.7 $MMTCO_2e$ in 2050, driven mainly by continued growth in natural gas production. Despite decreases in coal production (driven by market preferences), the concurrent increase in natural gas production will lead to a net increase in fugitive emissions from these fuel sources (see Figure 9). Non-fuel use 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 global warming potential gases resulting from the expected phaseout of HFCs.[18] Industrial emissions of these gases, including HFCs, PFCs, and SF_6, are projected to fall from a peak of 8.4 $MMTCO_2e$ in 2019 to 0.96 $MMTCO_2e$ in 2050. Emissions from other industrial processes are projected to decrease less dramatically, from 9.1 $MMTCO_2e$ in 2005 to 5.6 $MMTCO_2e$ in 2050. Agricultural emissions increase very little, from 7.6 $MMTCO_2e$ in 2005 to 7.7 $MMTCO_2e$ in 2050. Waste emissions remain fairly constant, decreasing slightly from 5.1 $MMTCO_2e$ in 2005 to 4.6 $MMTCO_2e$ in 2020 before increasing to 6.1 $MMTCO_2e$ in 2050 because of increases in municipal solid waste and wastewater emissions.

Methodology

The BAU estimates for GHG emissions do not include additional GHG reduction strategies beyond the policies and programs already in place or for which significant developments are

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

underway, as of December 2020. The BAU scenario was modeled using the following data sources:

- **EPA's 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 were 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 in 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 (on combined head and power [CHP] systems, loads, and more)

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.[19]

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

[19] ICF's Integrated Planning Model (IPM®) provides integration of wholesale power, system reliability, environmental constraints, fuel choice, transmission, capacity expansion, and key operational elements of generators on the power grid in a linear optimization framework. For more information see https://www.icf.com/technology/ipm.

Pennsylvania's Energy Profile and Policies

The Commonwealth of Pennsylvania is a leading energy producer and supplier, which has historically contributed significantly to local economies. Pennsylvania's energy profile has become increasingly dynamic in recent decades, as both fossil fuel and clean energy generation have grown. These changes, however, have resulted in both challenges and opportunities for reducing GHG emissions. Additional opportunities remain for improving resilience in Pennsylvania's energy infrastructure and deploying new and diverse energy resources to result in assured energy supply and to mitigate the impacts of climate change. The Commonwealth is one of the nation's leading natural gas producers (second only to Texas), producing nearly seven trillion cubic feet of natural gas in 2019.[20] It also is a net energy exporter and the largest electricity generator in the PJM service region.[21] In 2019, there were more than 269,000 total traditional energy, energy efficiency, and motor vehicle jobs in Pennsylvania, accounting for 4.5% of the total workforce. Of those, more than 97,000 were clean energy jobs, mostly in the energy efficiency sector. Although clean energy jobs are growing faster than the statewide average, employers report difficulty finding enough candidates with the appropriate experience, training, and skills.[22]

PA Policies Informing the BAU Scenario

- **Act 129.** Act 129 requires PA's seven largest electric distribution companies (EDCs) to reduce energy use in their service territory.
- **Alternative Energy Portfolio Standard.** AEPS sets targets for the amount of electricity supplied by PA's EDCs that must come from renewable sources. Policies in place as of December 2020 (2022 requirements) are projected to remain consistent through 2050.
- **Regional Greenhouse Gas Initiative.** By joining RGGI, Pennsylvania commits to reducing its GHG emissions in coordination with other member states. Policies in place as of December 2020 (2030 requirements) are projected to remain consistent through 2050, as RGGI will not take effect in Pennsylvania until 2022.
- **HFC Phaseout.** PA will phase out HFCs in accordance with the Federal AIM Act.

Falling costs for renewable energy and policies such as the AEPS, and recent requirements such as in-state solar generation to meet AEPS thresholds, have boosted the share of renewables in the energy mix. Zero-emission energy generation in Pennsylvania relies heavily on nuclear power, and the Commonwealth is the nation's second-largest generator of electricity from nuclear power.[23] Additionally, DEP is undertaking a rulemaking process to enable Pennsylvania to join RGGI. Participation in RGGI could lead to a significant increase in clean energy program

[20] EIA. 2021. "Pennsylvania State Profile and Energy Estimates." https://www.eia.gov/state/?sid=PA#tabs-3.
[21] PJM is the regional transmission organization that operates the electricity grid that serves Pennsylvania.
[22] DEP. 2020. "Workforce Development." https://www.dep.pa.gov/Business/Energy/OfficeofPollutionPrevention/EnergyEfficiency_Environment_and_EconomicsInitiative/Pages/Workforce-Development.aspx.
[23] EIA. 2021. "Pennsylvania State Profile and Energy Estimates." https://www.eia.gov/state/?sid=PA#tabs-3.

funding, beginning in 2022.[24] Oil and coal are still produced and used, despite reductions in the past decade, and the Commonwealth is still the third-largest coal-producing state.[25]

Energy efficiency has also become a significant source of emission reductions 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. One in six households in Pennsylvania uses fuel oil as a heating source—most of these households are in rural areas.[26] The industrial sector in Pennsylvania has a large footprint—with natural gas and oil extraction and mining, metals and machinery manufacturing; chemical products, and agriculture and food processing—and its electricity and fuel consumption continues to grow. Because of its expansive geography and large rural and urban areas at opposite ends 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 are prevalent. To promote a clean energy transition in the transportation sector, DEP is also engaged in the development, outreach, and monitoring of the Transportation and Climate Initiative.

Federal policies may influence Pennsylvania's energy and climate strategies

- The Biden Administration's American Jobs Plan, if enacted, would create funding that could support a number of Pennsylvania's energy and climate strategies.
- A successor EPA rulemaking to the 2015 Clean Power Plan, if promulgated, could require states to develop powerplant GHG reduction plans.
- Congressional Clean Energy Standard legislation, if enacted, could set power sector targets for renewable power.
- A new federal Corporate Average Fuel Economy standards regulation, if promulgated, could accelerate vehicle electrification strategies.

Pennsylvania's Energy and Climate Efforts and Commitments

Past and ongoing efforts in Pennsylvania to use energy more efficiently and promote the use of clean energy have decreased emissions and will help ensure that the 2025 goal of reducing net GHG emissions by 26% from 2005 levels is met.

Pennsylvania has implemented or committed to the following notable energy and environmental programs and policies since the early 1990s:

- Act 213—Alternative Energy Portfolio Standards (AEPS) (2004)
- Act 70—Pennsylvania Climate Change Act (2008)

---

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

[25] EIA. 2021. "Pennsylvania State Profile and Energy Estimates." https://www.eia.gov/state/?sid=PA#tabs-3.

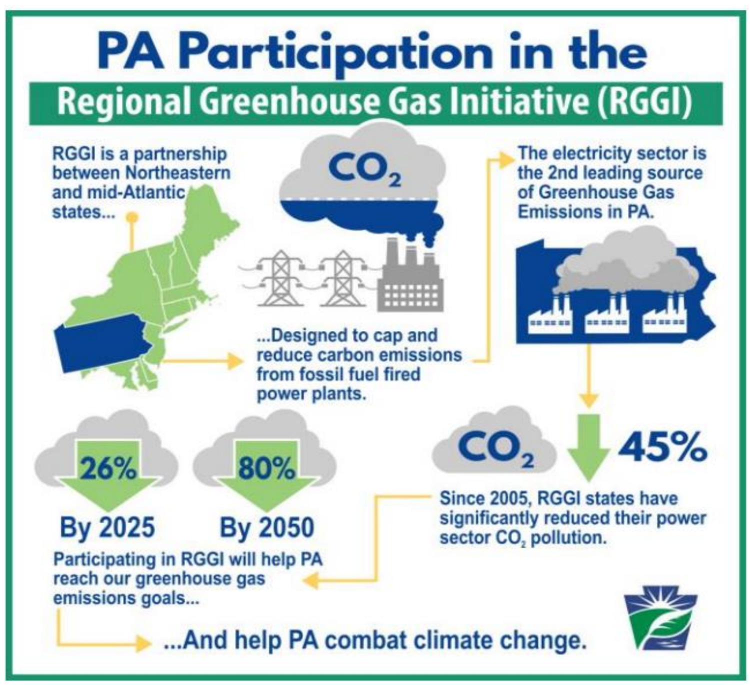
[26] EIA. 2021. "Pennsylvania State Profile and Energy Estimates." https://www.eia.gov/state/data.php?sid=PA#ConsumptionExpenditures

- Act 129—Energy Efficiency and Conservation Program (2008)
- Act 30—Commercial Property Assessed Clean Energy Program (C-PACE) (2017)
- Act 40—Solar Renewable Energy Credits (2017)
- Medium- and Heavy-Duty Zero Emission Vehicle MOU
- Governor's Executive Order 2019-01, which set GHG reduction goals for Pennsylvania and sustainability goals for Commonwealth agencies (2019), and
- Governor's Executive Order 2019-07, which enabled Pennsylvania to join RGGI (2019).

While few of these efforts were solely climate policies or programs, these all have had an impact on GHG emissions and are assisting with a transition to cleaner and renewable sources of energy. Listed below are a number of other ongoing efforts which contribute to reducing GHG emissions and improving resilience in Pennsylvania:

- **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 power purchases for state buildings.
- **Control of Emissions from Oil and Gas Operations rulemaking**—requires the reduction of VOC emissions from natural gas well sites, compressor stations and along pipelines, which reduces methane emissions as a co-benefit. This not only contributes to climate change mitigation, but also helps 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 more than 100 steps to strengthen resiliency to climate change impacts.
- **PennDOT's vulnerability study**—helps anticipate the impacts of extreme weather events so that transportation funding and resiliency may be prioritized.
- **RGGI**—reduces GHG emissions from the power sector while also generating economic growth. It sets a regional cap on emissions from electric power plants (see Figure 12).

Figure 12. Summary of Pennsylvania's participation in RGGI



- **Zero Emission Vehicle (ZEV) Program**—adopts parts of the California Air Resource Board's standards to control smog-causing pollutants and GHG emissions of light-duty vehicles as part of the Advanced Clean Cars package. The draft proposed rulemaking to adopt these standards is still under development by DEP.
- **Medium- and Heavy-Duty Zero-Emission Vehicles MOU**—advances and accelerates the market for medium- and heavy-duty electric vehicles.
- **Electric Vehicle (EV) Pennsylvania Roadmap**—expands the EV knowledge base, documents baseline EV data, and identifies near-, mid-, and long-term strategies to incentivize and remove barriers to EV adoption.
- **Drive Electric PA (DEPA) Coalition**—promotes collaboration between DEP and stakeholders statewide to increase the acceptance and adoption of EVs.
- **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. This initiative is a product of the Volkswagen Mitigation Trust Fund, a one-time penalty settlement that provided funds to establish grants and the rebate program.
- **Alternative Fuels Incentive Grant (AFIG)**—promotes the use of alternative fuels in Pennsylvania through four incentive programs: Alternative Fuel Vehicle Rebate for consumers, AFIG Program, Fixing America's Surface Transportation (FAST) Act Infrastructure Program, and Alternative Fuels Technical Assistance Program.
- **PEDA COVID-19 Restart Grant**—awarded $1.7 million in funding to restart 11 clean energy projects disrupted by the COVID pandemic in urban and rural areas, especially environmental justice neighborhoods. The projects were intended to rehire workers and hire additional workers to complete projects quickly, make immediate equipment payments to restart the supply chain, and overcome lost revenue caused by market stagnation. It also supported clean energy projects: four solar projects, three energy efficiency projects, one solar and energy-efficiency project, one EV charger project, and two high-performance building projects.
- **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 (in development)**—a facility that can translate and coordinate financing efforts and provide a communications bridge between contractors and finance providers to help finance clean energy projects. For example, it could provide product enhancements for small commercial and agriculture enterprises such as interest rate buy-down, loan loss reserve, and other credit enhancements to make financing more accessible. A Green Bank could also develop new mechanisms such as a specific finance product or market facilitation to connect Green Bank Partnership investments to private capital.
- **DEP's Local Climate Action Program** —allows local governments and college students to work together to develop GHG inventories and climate action plans.

- **Shared Energy Manager Program—**supported five jurisdictions that participated in DEP's Local Climate Action Program. The Shared Energy Manager supported those local governments in implementing energy-related strategies from their programs, such as energy benchmarking, energy audits, solar PV feasibility assessments, development of energy management plans, and alternative fuel evaluations for fleet vehicles.
- **PA Climate Leadership Academy—**strengthens the capacity of state and local government agencies, infrastructure organizations, and businesses to develop and implement sound climate change initiatives through comprehensive training programs.

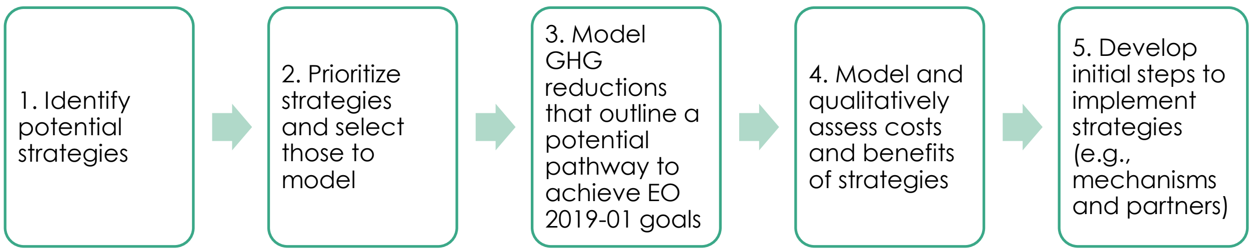
For more information about climate initiatives, visit DEP's website: https://www.dep.pa.gov. The next section describes additional opportunities for reducing GHG emissions in Pennsylvania.

3 OPPORTUNITIES TO SIGNIFICANTLY REDUCE 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



Potential Strategies

To start the GHG reduction strategy analysis, the ICF analysis team worked with DEP and CCAC in an iterative process to develop a comprehensive list of potential GHG reduction strategies. The completed list of potential GHG reduction strategies was 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 Program Plan
- A review of public survey data from DEP on the 2018 Climate Action Plan
- The ICF team's knowledge of trending and common strategies used across the country.

Prioritizied Strategies

After listing potential GHG reduction strategies, the analysis team worked with DEP and the CCAC to prioritize which strategies to model and evaluate. DEP developed the criteria for evaluating and prioritizing strategies with input from the CCAC and the ICF analysis team. These criteria are as follows:

- **GHG reduction magnitude**—considers the magnitude of potential GHG reductions from implementing the strategy.

- **Ease of implementation (legal, institutional)**—considers the potential barriers to implementation; whether significant time and resources would be needed to overcome legal or institutional obstacles; and whether existing programs, policies, or institutions could lay the groundwork for implementing the strategy.
- **Initial investment required**—considers the magnitude of up-front costs and capital investment required to implement the strategy.
- **Cost-effectiveness**—considers the cost of implementation compared to the magnitude of potential benefits.
- **Air quality and public health benefits**—considers potential air quality improvement and other potential health-related co-benefits.
- **Resilience benefits**—considers the potential to improve climate resilience.
- **Environmental justice and equitable implementation opportunity benefits**—considers the potential for improving environmental justice and designing implementation strategies that result in more equitable outcomes.

Criteria were weighted according to DEP's priorities: GHG reduction magnitude and cost-effectiveness were assigned the highest weight, followed closely by environmental justice and equitable implementation opportunity benefits and air quality and public health benefits. DEP then evaluated the potential strategies using these criteria and gave each strategy a cumulative weighted score.

Defining Environmental Justice and Equitable Implementation

Environmental justice embodies the principle that communities and populations should not be disproportionally exposed to adverse environmental impacts. Historically, minority and low-income Pennsylvanians have been forced to bear a disproportionate share of adverse environmental impacts. Addressing environmental justice means ensuring that all Pennsylvanians, especially those that have typically been disenfranchised, are meaningfully involved in the decisions that affect their environment and that no communities are unjustly and/or disproportionally burdened with adverse environmental impacts. Simply put, environmental justice ensures that everyone has an equal seat at the table.

Equitable implementation embodies the principle and commitment to promote fairness and justice in the formation of public policy that results in all residents—regardless of age, race, color, sex, sexual orientation, gender identity, religion, national origin, marital status, disability, socio-economic status, neighborhood of residence, or other characteristics—having opportunity to fully participate in and benefit from program or policy opportunities.

After scoring the strategies, DEP selected the subset that aligned best with the Commonwealth's goals, needs, and interests. DEP then worked with ICF to determine which strategies to model for GHG reductions, costs, and benefits. Table 2 summarizes the selected strategies, implementation timeframe, and whether the strategy is quantified. Strategies are described in greater detail in the following sections. Modeled strategies are labeled A through R for ease of reference throughout this plan. Timeframes of potential implementation are defined as near term (1 to 5 years), midterm (5 to 10 years), or long term (10+ years).

Table 2. Selected GHG reduction strategies by sector

Sector	GHG Reduction Strategy	Expected Implementation Timeframe	Quantified GHG Reductions, Costs and Benefits
Residential and commercial (R&C) buildings	A. Support energy efficiency through building codes	Near term	Yes
R&C buildings	B. Improve residential and commercial energy efficiency (electricity)	Near term	Yes
R&C buildings	C. Improve residential and commercial energy efficiency (gas)	Near term	Yes
R&C buildings	D. Incentivize building electrification	Midterm	Yes
R&C buildings	Introduce state appliance efficiency standards	Midterm	No
R&C buildings	E. Increase distributed on-site solar	Near term	Yes
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	F. Increase fuel efficiency of all light duty vehicles and reduce vehicle miles traveled for single occupancy vehicles	Midterm	Yes
Transportation	G. Implement the multi-state medium-and heavy-duty zero-emission vehicle memorandum of understanding	Long term	Yes
Transportation	H. Increase adoption of light-duty electric vehicles	Midterm	Yes
Transportation	I. Implement a Low Carbon Fuel Standard	Midterm	Yes
Industrial	J. Increase industrial energy efficiency and fuel switching	Near term	Yes
Fuel supply	K. Increase production and use of biogas/renewable gas	Midterm	Yes
Fuel supply	L. Incentivize and increase use of distributed Combined Heat and Power	Near term	Yes
Fuel supply	M. Reduce methane emissions across oil and natural gas systems	Midterm	Yes
Electricity generation	N. Maintain nuclear generation at current levels	Near term	Yes
Electricity generation	O. Create a carbon emissions free grid	Long term	Yes
Agriculture	P. Use programs, tools, and incentives to increase energy efficiency for agriculture	Near term	Yes
Agriculture	Q. Provide trainings and tools to implement agricultural best practices	Midterm	Yes
LULUCF	R. Increase land and forest management for natural sequestration	Midterm	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

Modeling and Analysis Approach

GHG Reduction Accounting Approach

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

- Reductions in GHG emissions resulting from reductions in direct fuel use for energy other than electricity are represented in the end-use sector (i.e., residential, commercial, industrial, or transportation).
- Reductions in GHG emissions resulting from changes in end-use electricity consumption are not included in totals to avoid double counting GHG reductions from different sectors and actions.
- Reductions in GHG emissions resulting from changes in electricity consumption and the generation mix are accounted for in the electricity generation sector. This is aligned with the GHG accounting approach used in the GHG inventory. GHG emissions from electricity generation are modeled in a two-step process:
  - Estimate changes in electric load resulting from strategies that affect load (e.g., energy efficiency, electrification).
  - Feed load changes over time into the Integrated Planning Model© with future assumptions to estimate generation mixes over time.

The GHG modeling layers the impacts of certain strategies to avoid overestimating reductions. Strategies are layered in order of potential implementation to account for interactions between them (e.g., a strategy that targets improving fuel efficiency standards may reduce overall fuel consumption; a second strategy that targets electric vehicle adoption incorporates the impacts of more fuel-efficient vehicles on the road at the outset to assess the impact of the second strategy on GHG emissions).

Economic Benefits and Costs

Large-scale transformational change, such as the change required to achieve large reductions in GHG emissions, will require investment and have associated costs. However, such changes, particularly reducing GHG emissions, can have economic benefits and improve air quality, and therefore reduce healthcare and health-related costs. For example, while there is a significant initial capital cost to install EV infrastructure, in the long term, the infrastructure will incentivize the transition to EVs, which can ultimately create savings from decreased fuel use and reduced environmental impacts. As is the case with most investments, a higher portion of costs are incurred at the outset, while the benefits grow and accumulate over time.

Analyzing the net costs and benefits of a strategy determines the cost-effectiveness of the strategy. A strategy does not have to have greater benefits than costs to be cost-effective, rather the costs have to be worth the benefits gained—some benefits are worth paying for.

To assess the cost-effectiveness of the strategies presented in this plan (a requirement of Act 70), multiple factors were considered: net present value (NPV), cost per $MTCO_2e$, number of jobs, gross state product, and personal income.

Net present value (NPV): Many of the GHG reduction strategies were analyzed to determine the economic benefits and costs. Potential capital costs, maintenance and repair costs, and the fuel and energy costs associated with implementation of each strategy were calculated. If the GHG reduction strategy results in net savings, i.e., the benefits are greater than the costs, then the NPV is displayed as a positive value. A negative NPV does not indicate that a strategy is not cost-effective, only that the monetized costs are greater than the monetized benefits.

Cost per $MTCO_2e$: For each GHG reduction strategy, the cost to implement it (in present value dollars) is divided by the total $MTCO_2e$ reduced through 2050 by implementing the strategy. The result of the calculation is the average cost to reduce 1 $MTCO_2e$. This metric can be used to help determine the cost-effectiveness of a strategy by comparing it to the social cost of carbon as a benchmark. If the cost per $MTCO_2e$ of the strategy is less than the benchmark, it could be considered cost-effective.

Social cost of carbon

The social cost of carbon (SCC) is a monetized "value of the net harm to society associated with adding a small amount of that GHG to the atmosphere in a given year. In principle, it includes the value of all climate change impacts, including (but not limited to) changes in net agricultural productivity, human health effects, property damage from increased flood risk natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services."

The SCC benchmark for 2020 is $116/ $MTCO_2e$.

Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990; Interagency Working Group on Social Cost of Greenhouse Gases, United States Government; 2021.

Employment (number of jobs), gross state product, and personal income: To better understand the macroeconomic impacts of GHG reduction strategies in greater detail, the REMI[27] model was used to estimate the impacts on employment and state economic output, as measured by the gross state product (GSP), and disposable personal income (DPI) for Commonwealth residents. The costs and savings estimated in NPV calculations (capital costs, maintenance and repair costs, fuel and energy costs) are modeled within REMI to determine the aggregate economic impacts. Costs and benefits are aligned with different sectors (e.g., residential, commercial, industrial, and transportation) and different industries (e.g., construction, manufacturing, trade, and services) to capture impacts accurately. REMI links

[27] REMI is a popular macroeconometric forecasting and policy analysis model that combines aspects of input-output modeling with computable general equilibrium techniques to create a hybrid economic modeling framework. The model has been used extensively in these types of macroeconomic modeling and forecasting studies in jurisdictions across the country. The model is dynamic, meaning it can be used to evaluate changes over time and allow changes driven by inputs from one year to carry through multiple years. Its dynamic nature enables robust forecasting techniques and estimation of distributional impacts on sectors and regions. Key outputs include employment, economic output or gross state product, and disposable personal income.

industries together so that interactions between individual industries can be captured both upstream and downstream. The links are contained in an economywide input-output matrix based on historical data that is forecasted for each year of the scenarios.

Given the transformational changes inherent in the strategies being modeled, relationships between economic and industrial sectors in the Commonwealth are likely to adapt and evolve to the changing economy. Although the REMI model does attempt to *predict* some changes in its forecasted relationships, uncertainties in the modeling results will remain. If a strategy has positive impacts on employment, GSP, and disposable income, these are represented by positive values in the strategy results, and if a strategy has negative impacts in some years (i.e., fewer jobs, lower GSP), these are represented by negative values.

These modeled cost-effectiveness measures do not consider potential co-benefits and costs such as improvements to environmental quality or public health, nor do they consider equity or environmental justice.

All dollars presented in the plan are representative of 2019 dollars.

Co-Benefits and Costs

GHG reduction strategies can result in positive economic, environmental, and social impacts—known as co-benefits. Co-benefits include improved air quality, health outcomes, safety, equity, and more. Co-benefits can be direct, such as energy efficiency measures that reduce energy consumption, or indirect, such as the reduced energy consumption from energy efficiency measures leading to a reduced reliance on imported energy and therefore increased energy security.

Many GHG reduction strategies could result in co-benefits, and these were considered in the evaluation and prioritization process. Some GHG reduction strategies had moderate climate benefits, but when all additional co-benefits were considered, may result in greater overall benefits than some strategies with greater climate benefits. Considering and quantifying co-benefits helps to make more informed decisions. Co-benefits may also create additional economic benefits that may not be captured elsewhere. For example, increased resilience to extreme weather events will reduce costs associated with inaction, or costs that may have otherwise been incurred as a result of events such as prolonged blackouts due to extreme heat (e.g., resulting businesses not being able to fully function, or manufacturing needing to slow). Finally, it encourages decisionmakers to consider and avoid or mitigate undesired impacts of GHG reduction strategies.

In addition, all GHG reduction strategies reduce the need for adaptation in the long term and thus provide long-term adaptation and economic benefits. In addition, several strategies focused on GHG reduction will have immediate adaptation co-benefits, and vice versa; these relationships are highlighted throughout the CAP.

Environmental Justice and Equity

In the context of this CAP, the term equity refers to the commitment to promote fairness and justice in the formation of public policy that results in all residents having the opportunity to fully participate in and benefit from program or policy opportunities**.** GHG reduction strategies have the potential to advance equity by improving air quality in disproportionately impacted communities, reducing energy costs for low-income households through building weatherization and strategic electrification, increasing transit options in areas with low accessibility, and more.

In general, any given GHG reduction strategy's capacity to benefit or detract from equity depends in part on how the strategy is designed and implemented. Strategies focused on increasing electric vehicle adoption provide a good example of the complexities of determining equity in GHG reduction strategies. There are equity benefits inherent to the strategy, as reduced tailpipe emissions lead to lower air pollution near roadways, thus helping to mitigate disparities in exposure to air pollutants from vehicles.[28] A counterargument to the tailpipe emission reduction benefit is that increased adoption of electric vehicles also leads to increased electricity generation, so potential disparities in exposure to stationary-source air pollution from power plants must be considered as well. However, as the electricity generation sector is decarbonizing, it results in the elimination of criteria pollutants at a much faster rate; this, combined with the greater efficiency of electric vehicles, makes vehicle electrification a preferable strategy to lower net emission impacts from transportation.

Finally, a strategy can be made more equitable by providing a set of clean energy options to consumers. Using the example of electric vehicles, incentives that rely on tax credits largely benefit population segments whose income allows for large tax breaks. That is why point-of-sale vouchers or special low-income loan programs are increasingly being implemented to benefit those who cannot afford high up-front costs and do not have the credit requirements for a loan. Car-sharing programs that incorporate electric vehicles are also becoming popular for providing access to clean mobility without requiring private vehicle purchases. These solutions are becoming popular in low-income and other disadvantaged communities, and they are well received by the public because they offer the co-benefits of reducing road and parking congestion and advancing sustainable land use.

Equity was considered and integrated into the evaluation and prioritization of the GHG reduction strategies. Strategy-specific considerations related to equity are included in the implementation recommendations below.

[28] "Populations on the lower end of the socio-economic spectrum and minorities are disproportionately exposed to traffic and air pollution and at higher risk for adverse health outcomes." See Pratt, et al. 2015. Page 5368. *Traffic, Air Pollution, Minority and Socio-Economic Status: Addressing Inequities in Exposure and Risk*.

Pennsylvania's Pathway to 2050

Key Insights

The following are highlights of key results of the modeled GHG reduction strategies, which include GHG emission reductions and different measures of cost-effectiveness (i.e., costs, jobs, economic growth). Health and social benefits were also analyzed outside of quantitative modeling efforts.

By implementing all modeled strategies, Pennsylvania will likely exceed the 2025 target of reducing GHG emissions 26% below 2005 levels. Strategies to reduce GHG emissions from fuel supply and industrial sources will play a key role.

Reaching Pennsylvania's 2050 target of reducing GHG emissions 80% below 2005 levels will require the implementation of all modeled strategies in all sectors. Strategies to reduce GHG emissions from electricity generation offer the greatest potential for reductions through 2050, followed by strategies to reduce emissions from transportation, industrial sources, and buildings. Nuclear and renewable sources will need to produce nearly all the electricity generated in Pennsylvania by 2050.

If the strategies described in this CAP are implemented, they would:

- **Generate over one million cumulative job-years[29] in the Commonwealth by 2050**, with an annual average of roughly 42,000 jobs per year, an increase of about 0.51% in average annual terms.
- **Result in little effect on economic growth while promoting a more environmentally sustainable future for Pennsylvania**. The average annual GSP decreases from BAU marginally by 0.01% overall, but rises in later years with an equivalent GSP increase of about 0.1% annually by 2050. Thus, the Pennsylvania economy continues to grow robustly with CAP strategies in place and the changes in GSP being on the margin, without affecting the overall growth path of the state economy. Similar patterns are expected for personal income changes as well, with slight annual decreases in early years, followed by slight annual increases in later years. The Commonwealth economy continues to grow with these strategies in place, but at a slightly slower rate than without any action to reduce emissions to mitigate the impacts of climate change.
- **Be cost-effective on a cost per $MTCO_2e$ reduced basis when considered together as a cohesive approach to reducing GHG emissions in the Commonwealth.** Additionally, most strategies result in co-benefits such as improved air and water quality, improved health outcomes, increased energy security, and improved equity and environmental justice outcomes.

[29] A job-year is defined as one year of work for one person. For example, a new construction job that lasts five years is five job-years.

Modeling Results

Pennsylvania's 2025 and 2050 GHG reduction targets can be met by implementing strategies in all sectors. Figure 14 demonstrates a potential pathway to an 80% reduction from 2005 levels by 2050, with a total reduction of 161.6 $MMTCO_2e$ beyond BAU levels. These results show that the 2050 reduction target could be met—but barely (reaching less than 1 $MMTCO_2e$ above target reductions). The 2025 reduction target could be exceeded by nearly 16.0 $MMTCO_2e$ with full implementation of the modeled strategies. Figure 15 shows the cumulative reductions by sector through 2050.

Figure 14. GHG reductions by strategy, through 2050 ($MMTCO_2e$)

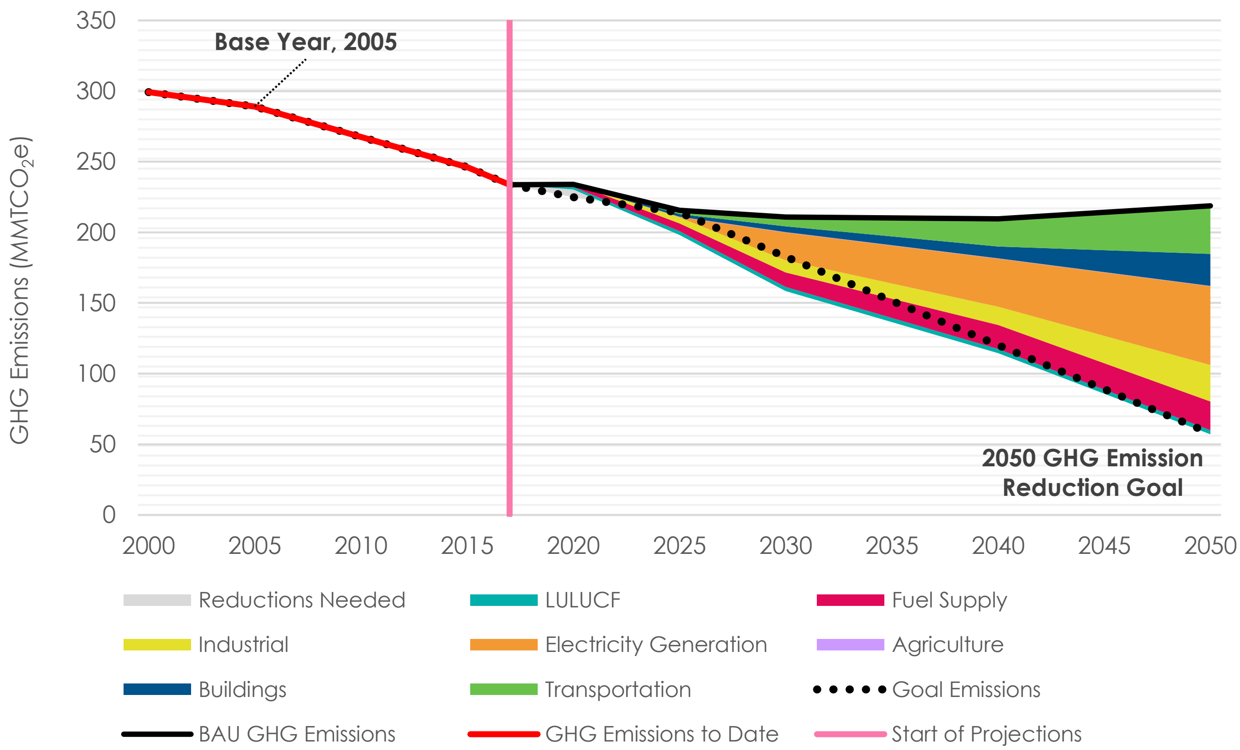
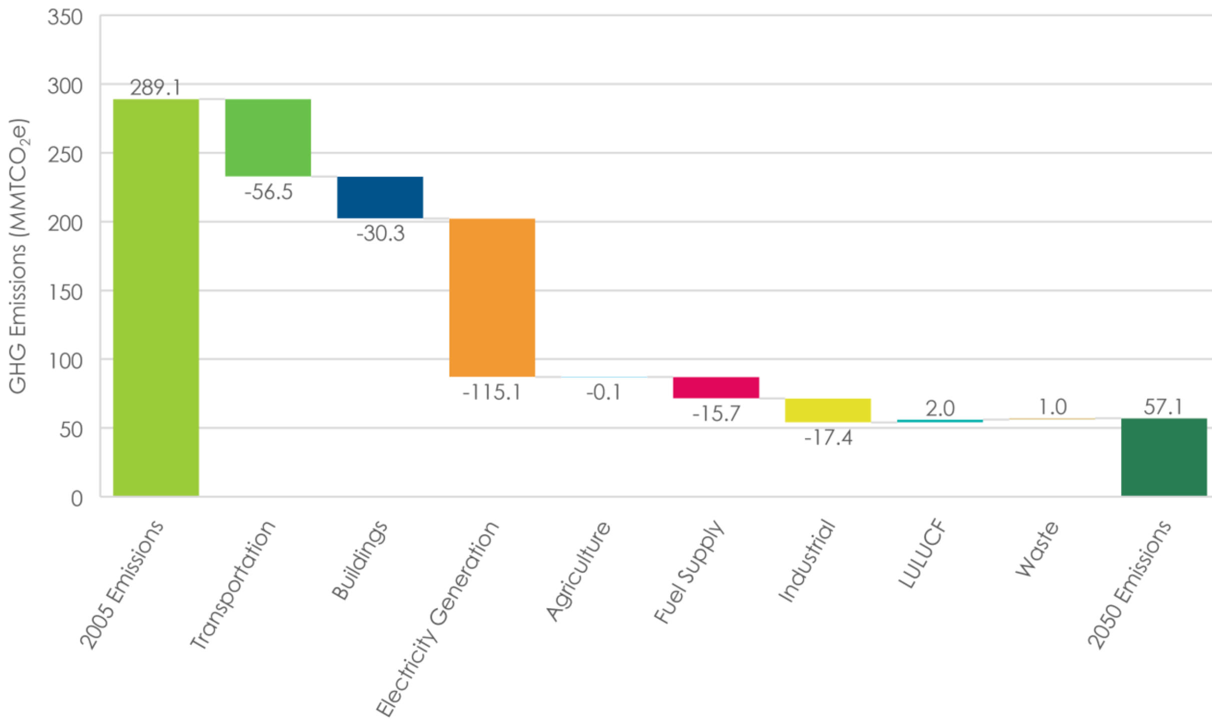


Figure 15. Cumulative GHG reductions by sector, 2005-2050 ($MMTCO_2e$)



Fuel supply and industrial GHG reduction strategies will play a major role in the near term, respectively contributing 32% and 25% of GHG reductions in 2025 (Figure 16). Electricity generation reductions are not included in Figure 16 because those emissions are projected to be higher in 2025 than in the BAU scenario for this sector. The initial increase in GHG emissions from electricity generation will eventually be reversed, and by 2050, strategies to reduce emissions from electricity generation, if fully implemented, will account for the most significant GHG reductions (Figure 17).

Figure 16. Sector share of total GHG reductions achieved through strategy implementation in 2025 ($MMTCO_2e$)

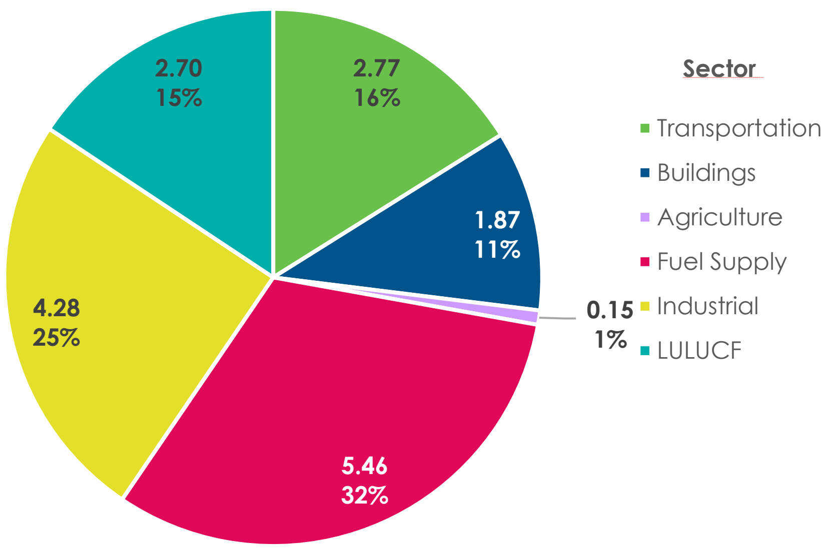
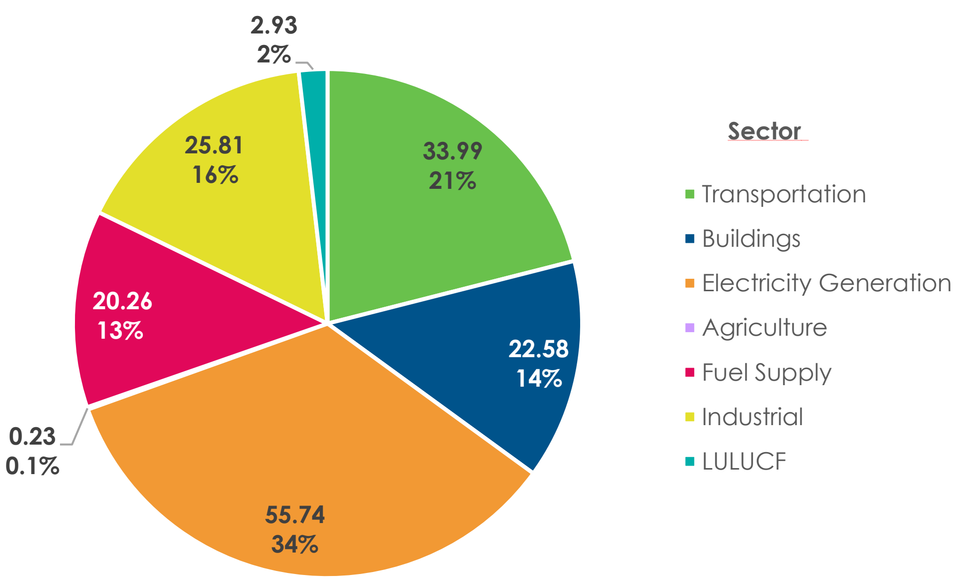
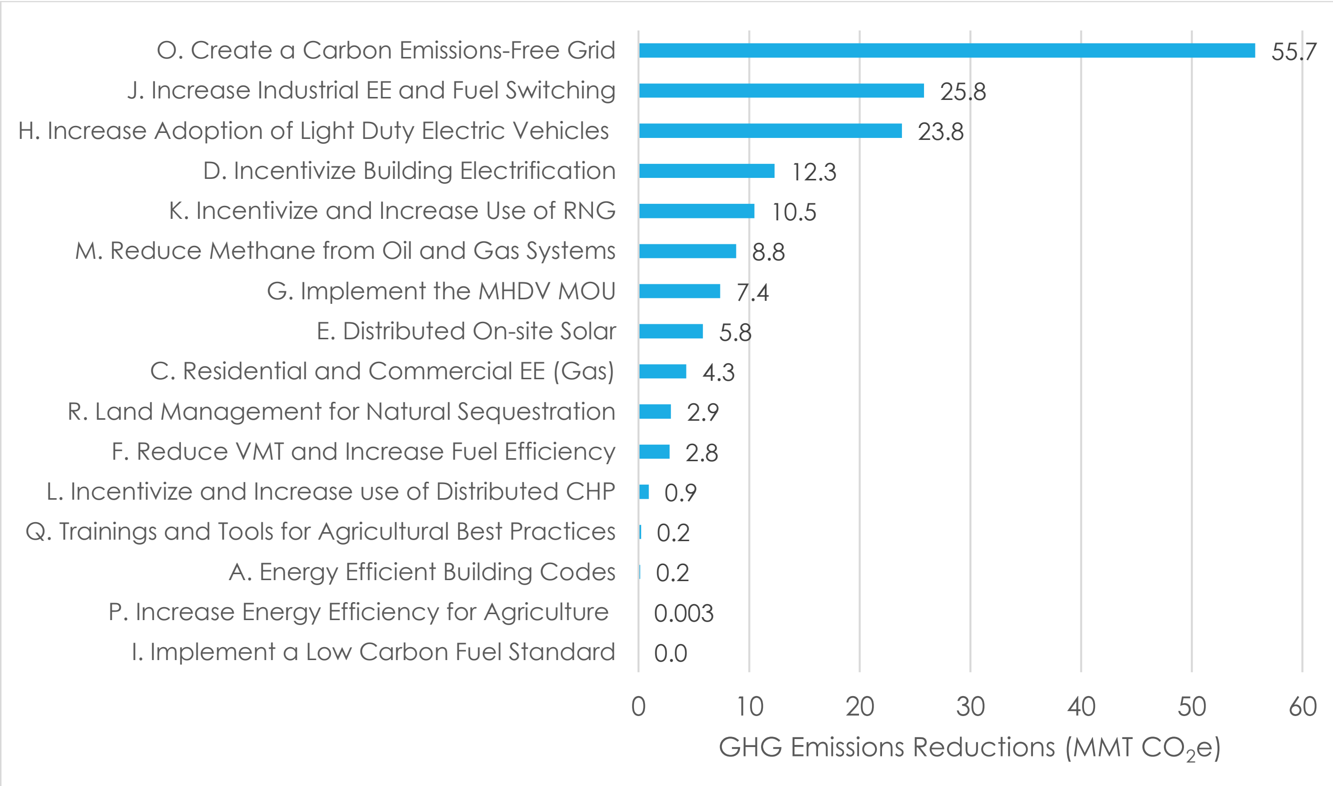


Figure 17. Sector share of total GHG reductions achieved through strategy implementation in 2050 ($MMTCO_2e$)



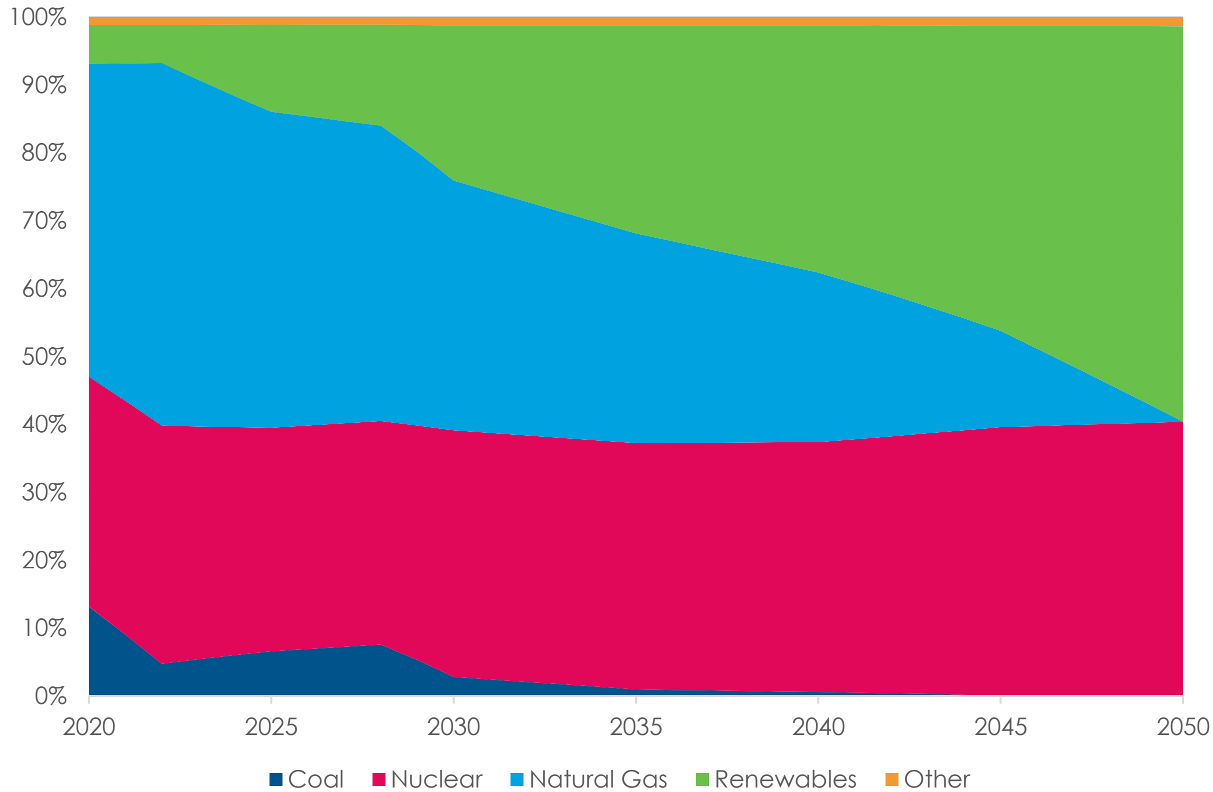
Although reductions in all sectors will be essential to reach Pennsylvania's GHG reduction targets, reductions from electricity generation, transportation, and building strategies will be responsible for the greatest cumulative reductions through 2050. GHG reduction from creating a carbon-free grid will have a gradual trajectory, but in 2050 it could reduce GHG emissions by 55.7 $MMTCO_2e$ compared to the BAU (Figure 18).

Figure 18. GHG reductions from strategies in 2050, compared to business as usual ($MMTCO_2e$)



If the prioritized strategies are fully implemented, the transition to a carbon-free grid would significantly reduce Pennsylvania's GHG emissions by 2050. This would be driven largely by a transition to clean renewable energy generation (e.g., solar), which will replace fossil-based generation such as coal and natural gas. Figure 19 shows a breakdown of electricity generation by source over time, from 2020 to 2050. In Figure 19 electricity generation from waste coal is included in the fuel type "Coal," and the "Other" fuel type includes electricity generation from waste-to-energy and landfill gas facilities. Nuclear generation is projected to remain at its current level, while renewables are expected to grow from roughly 6% of total generation in 2020 to 58% in 2050. Replacing GHG-intensive sources with carbon-free alternatives will contribute significantly to achieving Pennsylvania's GHG reduction targets. Pennsylvania is expected to be an electricity exporter in 2050, exporting approximately 4,000 GWh in 2050. This is much less than in 2020, when it exported about 72,000 GWh. To help balance the added intermittent renewable generation and to backfill the retiring fossil capacity, nearly 47 GW of four-hour battery storage capacity is added by 2050. New, enabling technologies (outlined later in this section) could also play a role in decarbonization of the electricity grid.

Figure 19. Electricity generation mix under a carbon-free grid scenario



Alternative electricity generation mixes

The electric grid strategies modeled in this plan provide one potential pathway toward a carbon free grid by 2050, however different market conditions or new enabling technologies have the potential to provide similar outcomes through a different grid mix. Alternatives could include enhanced roles for carbon capture use and sequestration technologies, hydrogen used for power generation, or additional distributed energy resources. The 80x50 model's grid mix presented provides geographic diversity and certain advantages, however other pathways might increase the diversity of generation types, while still providing reliable electricity.

In addition to reducing GHGs, strategies are projected to result in changes in energy use across sectors. Overall, natural gas, distillate fuel oil, and residual fuel oil consumption is anticipated to decrease, while consumption of electricity and renewable fuels such as biogas and biodiesel are anticipated to increase. Strategies in the buildings and transportation sectors are major drivers of the shift toward increased electricity consumption.

Many of the strategies also have the potential to provide co-benefits such as improved air quality, health, equity, and economic opportunities. The most economically beneficial strategies are those that reduce the cost of energy consumption. The building, fuel, and transportation sectors make up the bulk of the economic benefits, with job increases in most of their strategies.

Taken in isolation, the grid strategy appears to result in the largest decrease in economic activity, though many of the benefits of electrification that the grid strategy provides are captured in other strategies, so the attribution of strategy costs and benefits are somewhat subjective. The industrial and agriculture sector strategies also have small decreases in economic activity. The strategies offering positive economic impacts, however, more than offset these strategies. The annual number of jobs varies by year (e.g., in 2050, the total jobs supported by these strategies is about 80,000), with an annual average increase of about 42,000 jobs. Combined, the strategies would result in over one million cumulative job-years by 2050. To put these results in context, the macroeconomic impacts estimated here are relatively small compared to the size of Pennsylvania's economy. Annual employment impacts are estimated to range from roughly 0.1% increase to slightly less than 1.0% (in 2050) increase, which averages out to about a 0.51% increase annually for the entire modeling period. Figure 20 and Figure 21 summarize the cumulative employment impacts of all the strategies modeled in REMI.

Figure 20. Job trends—summary employment impacts under the 80x50 scenario

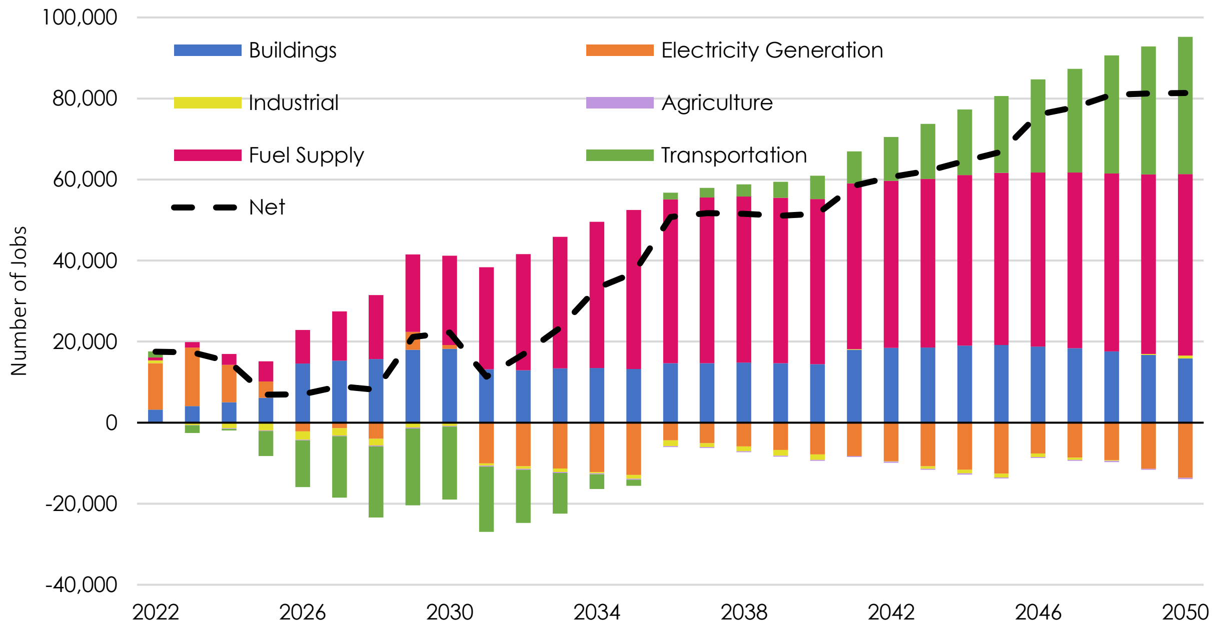
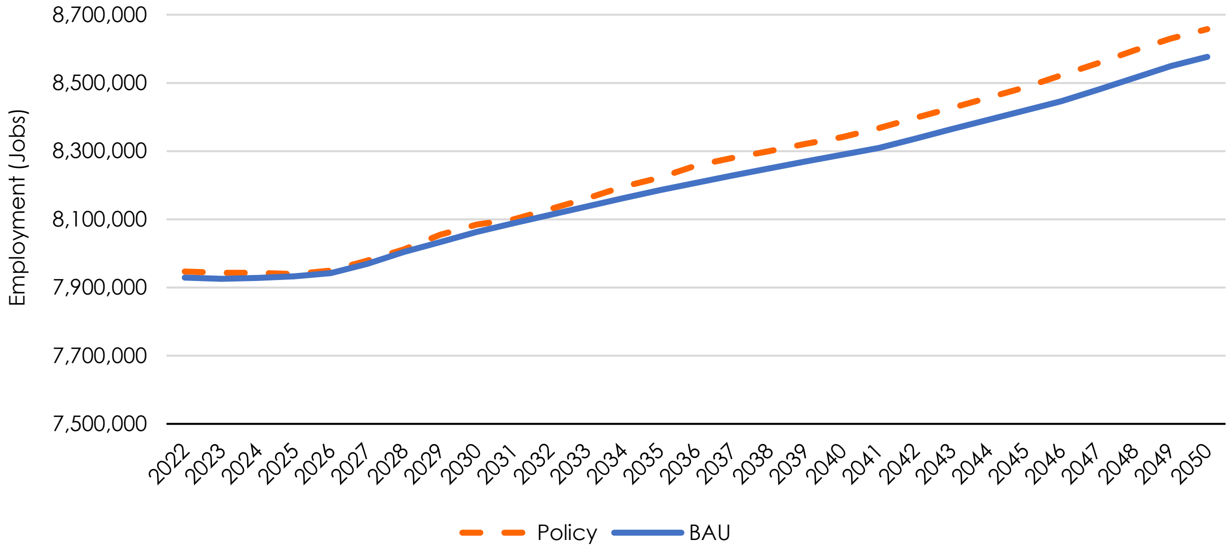


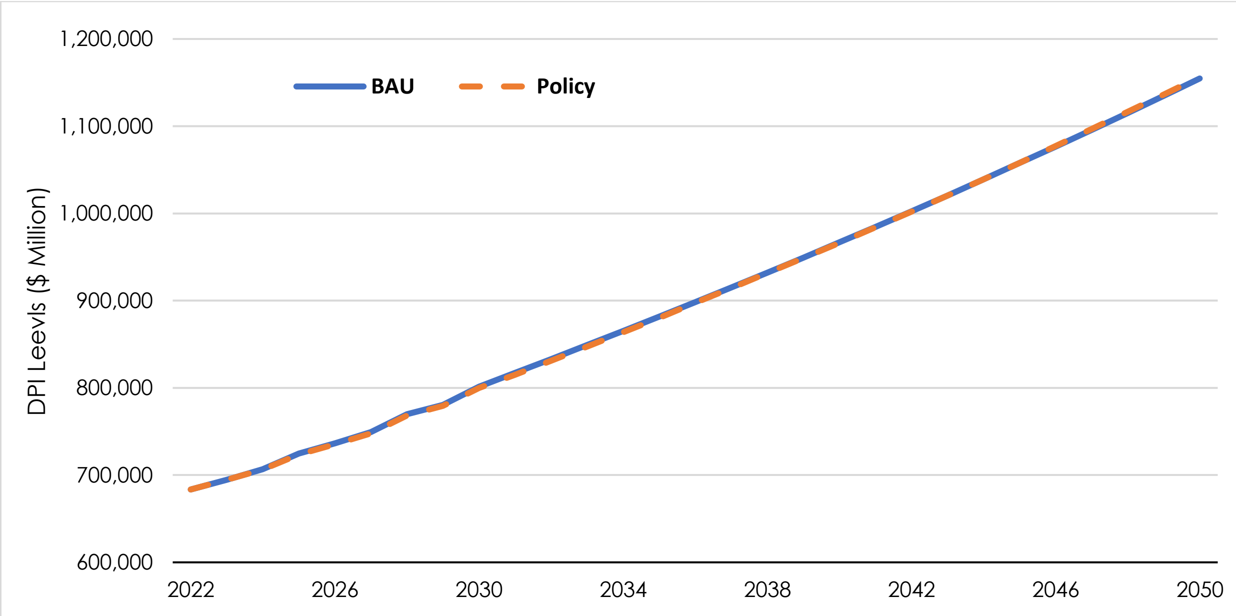
Figure 21. Employment levels under the business-as-usual and 80x50 scenarios



Employment data are from REMI. The BAU employment levels in REMI do not include the effects of COVID-19 on the Commonwealth economy and employment levels.

For GSP and disposable personal income (DPI), slight decreases from the BAU baseline are likely, with GSP decreases of about 0.01% and decreases in DPI of 0.06% in annual average terms. Although the annual average decrease in DPI appears more significant, at -0.06% per year, the Pennsylvania economy continues to grow robustly under the 80x50 scenario, and income levels continue to rise at rates very similar to the BAU baseline. As Figure 22 shows, the rates of growth in disposable income under the BAU and 80x50 scenarios are virtually indistinguishable.

Figure 22. Disposable income levels under the business-as-usual and 80x50 scenarios



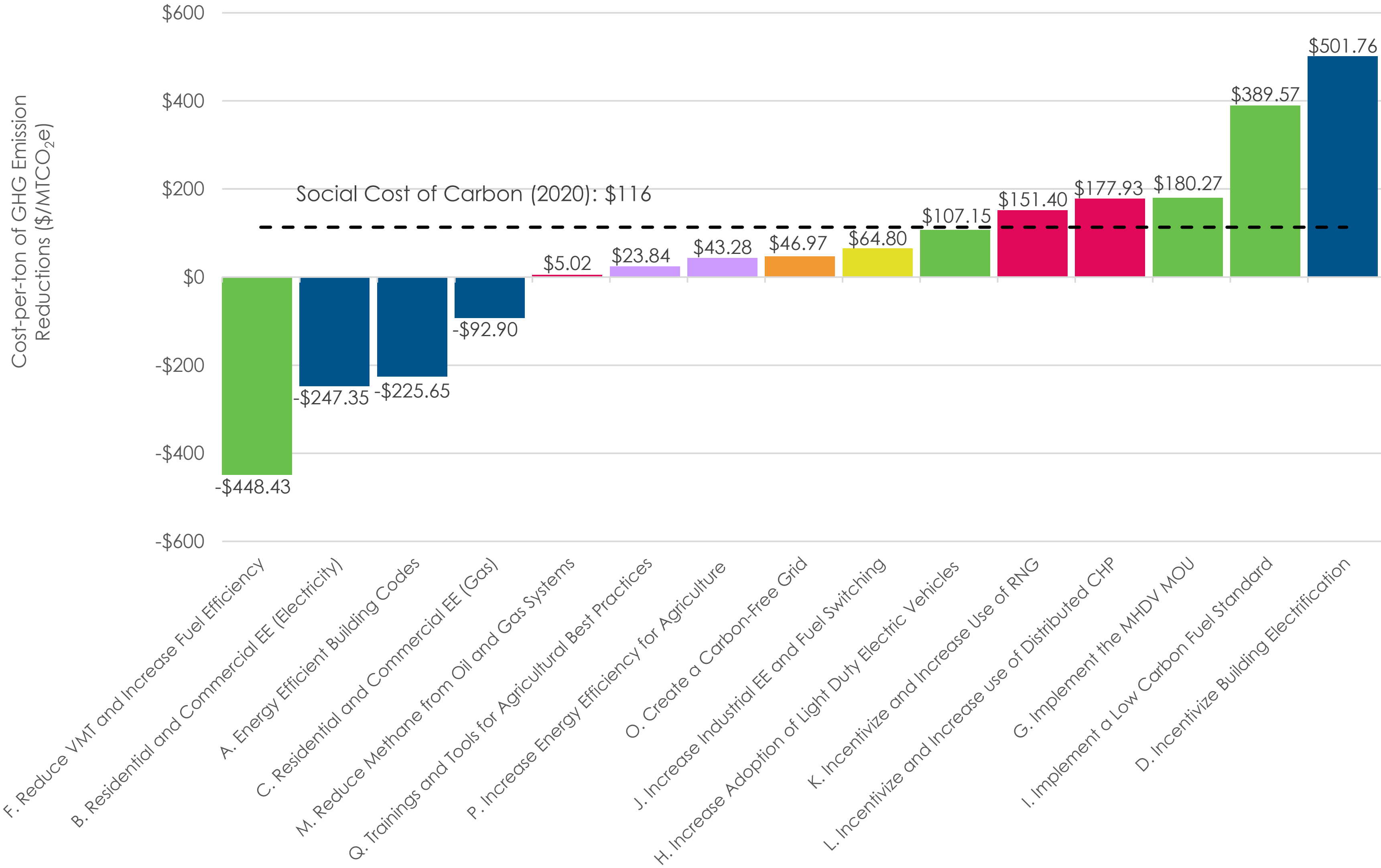
Several measures are used to determine the cost-effectiveness of a strategy, one of which is the cost per $MTCO_2e$ reduced. Using this measure, if the cost per $MTCO_2e$ of the strategy is less than the SCC benchmark ($116 per $MTCO_2e$ in 2020[30] or $113.20 per $MTCO_2e$ in 2019[31]), the strategy could be considered cost-effective. Figure 23 presents the cost per $MTCO_2e$ for each strategy, and Figure 24 presents these same results aggregated by sector. Most of the modeled strategies are cost-effective compared to the benchmark, and three of the strategies even result in cost savings (i.e., have a negative cost). Cost-effectiveness is not so black and white, however, and other measures of cost-effectiveness like NPV and macroeconomic effects like jobs and GSP should also be considered. In addition, unquantified effects such as increased equity and co-benefits should be qualitatively assessed to inform a more holistic evaluation of cost-effectiveness.

---

[30] *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990; Interagency Working Group on Social Cost of Greenhouse Gases, United States Government; 2021.*

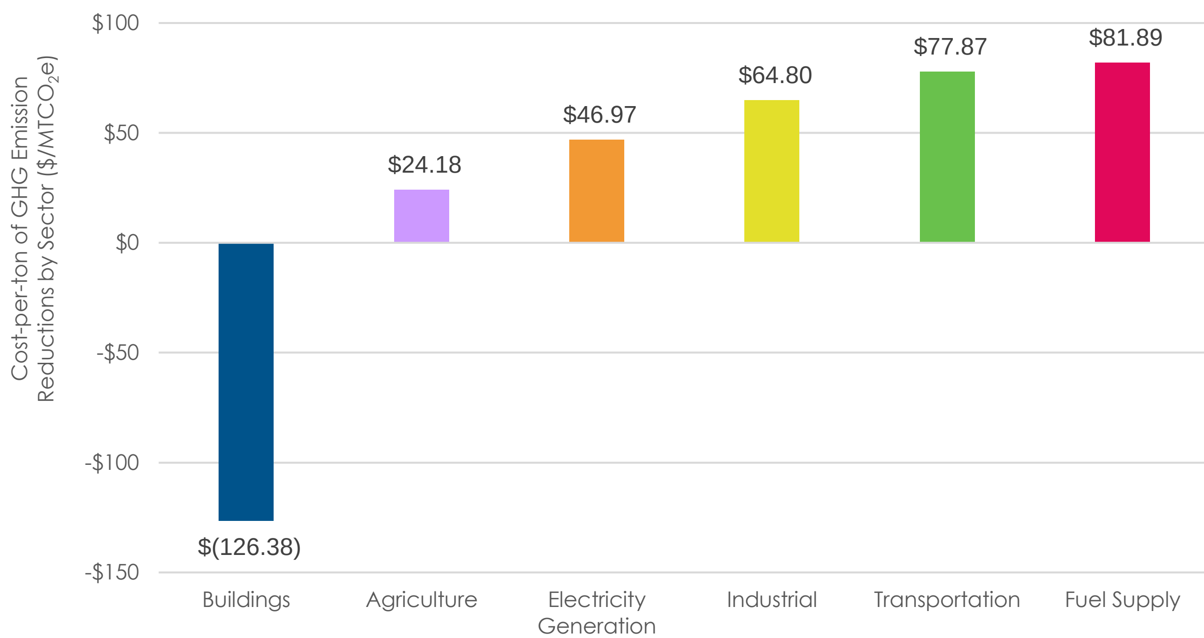
[31] Bureau of Labor Statistics Inflation Calculator: https://www.bls.gov/data/inflation_calculator.htm.

Figure 23. Cost per $MTCO_2e$ reduced ($/$MTCO_2e$) for all strategies compared to the social cost of carbon



Notes: Costs per $MTCO_2e$ reduced for land use-related reductions are not estimated. Costs for distributed solar (Strategy E) and nuclear electricity (Strategy N) are included in the costs for the carbon-free grid (Strategy O).

Figure 24. Cost per $MTCO_2e$ reduced ($/$MTCO_2e$) for all sectors



Residential and Commercial Buildings

The diversity in building types, vintages, and sizes of Pennsylvania's building stock presents a unique set of challenges to energy efficiency and GHG reductions in the buildings sector. The residential and commercial buildings sector includes homes, apartment complexes, businesses, institutional facilities (e.g., schools, hospitals), and other large buildings. These buildings typically burn fuel on site, primarily for space- and water-heating needs. Note that electricity use is not included in the building sector; it is included in the electricity generation sector. Emissions from the residential and commercial sectors have decreased 20% since 2005, mostly because of the transition to lower-emitting fuels, energy efficiency improvements that reduce the need for fuel consumption, and technological improvements. Strategies to improve building codes and energy efficiency, as well as increased electrification of heating, can help to reduce fuel burning and associated emissions.

There are just over 5 million residential buildings in Pennsylvania. The majority of Pennsylvanians live in detached single-family homes (66%), followed by attached single-family buildings (17%), multifamily buildings (14%), and manufactured or mobile homes (3%). On average, multifamily homes consume the least electricity per person, while detached single-family homes consume the most. The average home in Pennsylvania is 65 years old, about 1,900 square feet, and about 61% less efficient than a home built to 2009 IECC code.[32]

[32] Pennsylvania Public Utility Commission (PUC). 2019. 2018 Pennsylvania Statewide Act 129 Residential Baseline Study. https://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_Res_Baseline_Study_Rpt021219.pdf.

There are approximately 50,000 commercial buildings in Pennsylvania. Commercial buildings include office buildings, restaurants, grocery stores, retail shops, lodging, schools, hospitals, and warehouses. Most commercial buildings rely on natural gas for on-site energy supply used to heat spaces, heat water, and cook food.[33]

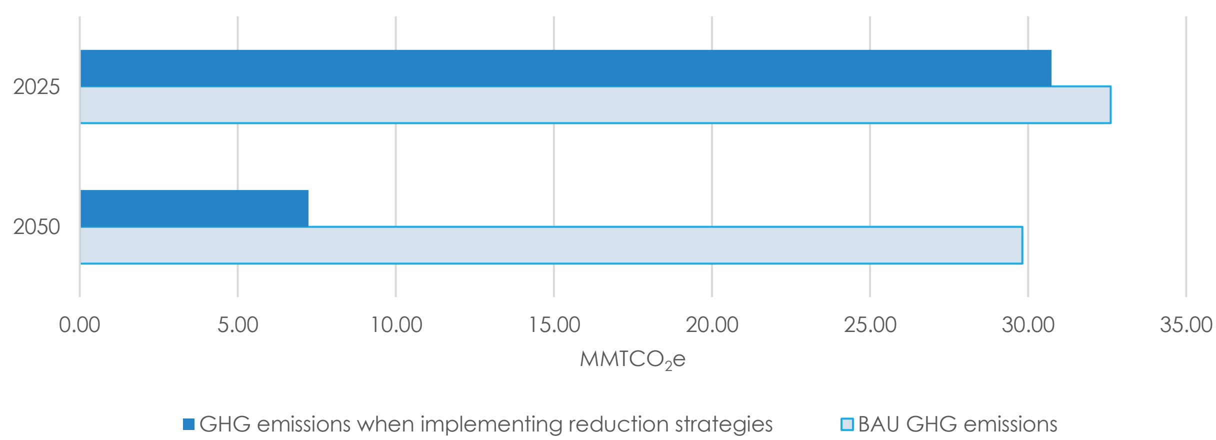
The strategies proposed to address building emissions reflect existing technological and policy trends that aim to improve energy efficiency, incentivize electrification, and add clean on-site energy production. Five strategies are modeled:

- Support energy efficiency through building codes
- Improve residential and commercial energy efficiency (electricity)
- Improve residential and commercial energy efficiency (gas)
- Incentivize building electrification
- Increase distributed on-site solar

Together, the modeling results indicate that these strategies will reduce emissions compared to the BAU in 2025 and 2050 (Figure 25), and in 2050 will reduce emissions in the buildings sector by 22,582,992 $MTCO_2e$ (Table 3).

For each strategy, the environmental, economic, and social benefits are reported along with the costs (or savings) associated with the implementation of the strategy. The environmental benefits and costs (or savings) are expressed in terms of GHG emission reductions and changes in energy and fuel use. The economic impacts are expressed in terms of changes in job numbers, DPI, and GSP. The social benefits and costs are expressed in terms of impacts on air quality (e.g., changes in the criteria pollutants like SO_2, NO_x, and $PM_{2.5}$) and associated public health and social impacts such as equity and resilience.

Figure 25. Building sector GHG emissions with reduction strategies compared to business-as-usual



[33] Pennsylvania PUC. 2019. 2018 Non-Residential Baseline Study: Pennsylvania Act 129. Available at: https://www.puc.pa.gov/Electric/pdf/Act129/SWE-Phase3_NonRes_Baseline_Study_Rpt021219.pdf.

Table 3. Building sector GHG reduction strategies and associated reductions ($MTCO_2e$)

GHG Reduction Strategy	2025	2050
A. Support energy efficiency through building codes	24,444	164,278
B. Improve residential and commercial energy efficiency (electricity)	N/A*	N/A*
C. Improve residential and commercial energy efficiency (gas)	1,365,613	4,311,296
D. Incentivize building electrification	483,807	12,288,250
E. Increase distributed on-site solar	296	5,819,168
Total GHG reduction	**1,874,160**	**22,582,992**

**The GHG reductions from this strategy are captured in the electricity generation sector.*

A. Support energy efficiency through building codes

This strategy includes adopting the most current building codes and training code officials and inspectors on how to enforce existing codes, as well as creating a single stretch code for PA Department of Labor and Industry approval to allow uniform adoption across the Commonwealth. This strategy could create codes based on existing "stretch codes" such as International Green Construction Code (IgCC), Zero Code, NetZero Codes, or allow the adoption of and promote the use of a Pennsylvania-specific stretch code.

Environmental benefits and costs

By reducing the amount of electricity and gas consumed through the adoption of more recent codes, this strategy reduces emissions of CO_2 and other GHG associated with electricity generation and fuel combustion, such as CH_4 and N_2O. This strategy also reduces gaseous and particulate emissions associated with electricity generation and combustion, including criteria pollutants such as NO_x, SO_x, $PM_{2.5}$, and volatile organic compounds (VOC) that are ground-level ozone precursors. Finally, energy savings can be expected from the adoption of newer codes.

Economic benefits and costs

The adoption and enforcement of the most current building codes will result in disparate economic impacts. Investments by the residential and commercial sectors and corresponding reductions in energy consumption will result in positive economic impacts. In paying for these investments, however, the residential and commercial sectors will see reductions in other expenditures (opportunity costs of their investments). The net impacts are positive, with an NPV of $13.97 billion. Average annual GSP and DPI impacts are negative, estimated at -$32.82 million and -$79.58 million annually, respectively. The average annual employment impact is expected to be -120 jobs.

Annual GHG emissions reduced in 2025

24,444 $MTCO_2e$ [a]

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 or (benefit) per ton of GHG reduced

$(225.65)/$MTCO_2e$

Net present value

$13.97 billion

Average annual gross state product

$(32.82 million)

Average annual disposable personal income

$(70.58 million)

Average annual employment

-120 jobs

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

Social benefits and costs

Adopting progressive energy codes improves air quality by reducing emissions from the combustion of natural gas and the generation of electricity. This strategy also provides a benefit to public health by directly reducing emissions that affect health. Homes built to a more efficient energy code may result in higher initial costs, but code updates typically provide lifetime savings for owners.

Energy Code Adoption in Pennsylvania

Residential. The Department of Labor and Industry (DLI) would use its authority to promulgate and upgrade the Pennsylvania Uniform Construction Code (UCC), through modifications subject to public hearings and approval by the DLI Review and Advisory Council (RAC). Residential energy code provisions are based on the International Code Council (ICC)'s triennial International Energy Conservation Code (IECC) and International Residential Code (IRC)

Commercial. DLI would update the commercial energy code provisions through the same overall process, but would draw on the IECC's commercial provisions, as well as those of ASHRAE Standard 90.1. In addition, 2017 state legislation enabled the City of Philadelphia to adopt a more stringent code for commercial buildings.

Implementation Considerations

Pennsylvania's building energy codes for commercial and residential construction are updated triennially under current law. The Commonwealth has a defined process for residential and commercial energy codes adoption. Pennsylvania can build on its recent progress by continuing to update building codes and allowing or incentivizing local "stretch" code adoption and high-performance or net-zero buildings.

Resilience Considerations

Changes that improve energy efficiency—whether through building codes or electrification, or residential or commercial energy-saving strategies—increase populations' resilience by decreasing costs. Energy efficiency also reduces building energy use, which can in turn reduce stress on the grid during heat waves (and the associated costs and risks of outages), and improve air quality—both important to mitigating health and economic risks in warmer temperatures.

In low-income households, where a higher proportion of income is spent on energy than in high-income households, cost-saving benefits may be particularly significant. For example, for communities that disproportionately lack access to methods of adapting to heat hazards (e.g., if the cost of air conditioning is a barrier), cutting energy costs—or preventing them from rising under warmer temperatures—through energy efficiency may increase those communities' resilience to a wide range of hazards.

New York and Massachusetts allow local jurisdictions to adopt "stretch" codes that exceed state minimum stringency. Creating a single stretch code for Pennsylvania would allow uniform adoption across the Commonwealth, which has many benefits. Consistency enables builders, developers, and code officials to implement energy-saving measures in construction practices. Local governments exercising their own development policy powers, such as granting bonus incentives and expedited permits for greater density, would encourage higher-efficiency new construction.

Energy codes such as IECC are governed by the International Code Council and are considered the national model code. Cost impacts associated with code updates are evaluated, and changes to the code typically provide a cost-effective balance of benefits to home and building owners. Cost-effectiveness tests for building codes are critical to ensure that cost and social equity considerations are accounted for. Code adoption has received generally positive political support in the past, with mixed opposition when codes are perceived to increase costs.

B. Improve residential and commercial energy efficiency (electricity)

This strategy includes several actions to improve residential and commercial energy efficiency by requiring energy-efficiency improvements aimed at reducing kWh used, either in the existing or in a modified framework of Act 129 and other programs (e.g., increasing savings targets and removing spending caps).

For Act 129, this may include increasing the low- to moderate-income (LMI) share of spending and reforming cost-effectiveness tests to support more LMI focus, in coordination with the Low-Income Usage Reduction Program (LIURP). Act 129 could also be enhanced by specifying a monetary value for avoided GHG emissions (as demonstrated by New York State's Value of Carbon guidance)[34] or by adding climate mitigation and resilience benefits to cost-effectiveness tests. To enhance Act 129 effectiveness and increase savings, incentives and education should also leverage programs such as the federally funded Low-Income Home Energy Assistance Program (LIHEAP) and Weatherization Assistance Program (WAP).

This strategy also calls for creation of a statewide commercial building energy performance program to reduce electricity use in large commercial buildings. Such a program could begin with the energy benchmarking of large facilities and grow to include retro-commissioning or energy efficiency requirements.

Annual GHG emissions reduced in 2025
Not included in totals[a]

Annual GHG emissions reduced in 2050
Not included in totals[a]

Annual energy reduced in 2050
21,948 GWH

Cost or (benefit) per ton of GHG reduced
$(247.35)/MTCO$_2$e

Net present value
$24.05 billion

Average annual gross state product
$1,212.47 million

Average annual disposable personal income
$1,058.56 million

Average annual employment
12,765 jobs

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

Environmental benefits and costs

By reducing the amount of electricity consumed by expanding energy efficiency, this strategy reduces emissions of CO_2, CH_4, and N_2O. This strategy also reduces gaseous and particulate emissions associated with electricity generation, including criteria pollutants such as NO_x, SO_x, $PM_{2.5}$, and VOCs. Finally, energy cost savings can be expected from the implementation of electrical energy efficiency.

Economic benefits and costs

Investments in electric energy efficiency result in positive economic impacts resulting from manufacturing and construction (installation) jobs, as well as from increasing residential disposable income and commercial expenditures directly resulting from

[34] New York State. Establishing a Value of Carbon Guidelines for Use by State Agencies. https://www.dec.ny.gov/docs/administration_pdf/vocfguid.pdf. Accessed April 4, 2021.

bill savings. Some negative impacts will result from the lost opportunity costs of investment and impacts to power generators from lost revenues. The NPV of this strategy is positive, at $24.05 billion. The cumulative economic impacts are positive because of increasing bill savings over time. Average annual GSP and DPI impacts are estimated at about $1.2 billion and $1.1 billion, respectively. The average annual employment impact is expected to be about 12,765 jobs.

Social benefits and costs

The implementation of energy efficiency measures improves air quality by reducing emissions from the generation of electricity. This strategy also provides a benefit to public health by directly reducing emissions that affect health.

Implementation Considerations

Improving residential and commercial electrical energy efficiency through incentive and retrofit programs is well established both in Pennsylvania and nationally. This strategy consists of two main programs, the expansion of Act 129 and the establishment and growth of a Commercial Building Energy Performance Program. Changes recommended by this strategy can be implemented immediately and can grow over time.

Reducing electricity usage in buildings can be accomplished through conservation and efficiency measures that result in a variety of environmental, social, and economic benefits. Energy conservation includes behavioral and operational measures and programs, such as changing temperature settings, turning off unused lights and energy-consuming devices, and reducing the operation hours for space conditioning and other systems. Through energy conservation, electricity users can achieve instant, albeit small, reductions through changes in how they use systems and buildings. Energy efficiency includes improving the operating performance of buildings through retrofitting and interventions such as the following:

- Building envelope improvements (e.g., better windows, insulation, and air sealing)
- New and more efficient appliances and equipment
- Lighting retrofits (e.g., LED and other advanced technologies)
- Changes to heating and cooling systems (e.g., ground-source heat pumps, variable refrigerant flow, and ductless systems).

Pennsylvania already implements Act 129, which sets electricity reduction targets for electric distribution companies to meet, but the state legislature would also have to increase annual energy savings targets, remove cost caps, and make other programmatic changes. Increasing the impact of Act 129 programs would also require complementary state legislative or regulatory action to reform rate-making and resource-acquisition policies, to provide incentives for investing in energy efficiency.

A commercial building energy performance program would be modeled on programs in other cities and states, including those in Philadelphia, Pittsburgh, Washington State, and New

Jersey.[35] Large buildings (over 50,000 square feet) would be subject to the program and would be required to benchmark their energy use in the initial years of the program. Over time, more energy performance measures would be added to ensure that large buildings use energy efficiently. To implement this program, the state legislature would have to pass legislation creating the program and would have to assign a regulatory agency to administer it.

Program rules for implementation should ensure equitable implementation and include the continuation of specialized low- and moderate-income programs for Act 129 to ensure that low-income individuals are not financially harmed. If the program included multifamily residential buildings in its design, environmental justice or low-income communities could be financially benefited by this strategy, but careful implementation would be required to avoid increasing financial burdens and disparities.

Energy efficiency programs have generally received broad support from policymakers and program stakeholders, provided that the programs continue to be cost-effective for participating parties. Expanding Act 129 is feasible given the many expected benefits of doing so, including job growth and cost savings.

[35] IMT. Map: U.S. City, County, and State Policies for Existing Buildings: Benchmarking, Transparency and Beyond. Accessed April 5, 2021. https://www.imt.org/resources/map-u-s-building-benchmarking-policies/.

C. Improve residential and commercial energy efficiency (gas)

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 a statewide commercial building energy performance program targeting the reduction of natural gas use in large commercial buildings. This type of program begins with energy benchmarking of large facilities and grows to include retro-commissioning or imposing energy efficiency requirements. It also includes an allocation of a certain portion of funds for LMI individuals and the updating of cost-effectiveness tests, such as by adding climate mitigation and resilience benefits to the tests. Act 129 could also be enhanced by including a monetary value for the avoided GHG emissions (as demonstrated by New York State's Value of Carbon guidance).[36]

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 or (benefit) per ton of GHG reduced
$(92.90)/$MTCO_2e$

Net present value
$7.35 billion

Average annual gross state product
$(55.79 million)

Average annual disposable personal income
$143.77 million

Average annual employment
1,396 jobs

Environmental benefits and costs

By reducing the amount of gas consumed through the implementation of gas efficiency measures, this strategy reduces emissions of CO_2 and other GHGs associated with gas combustion such as CH_4 and N_2O. This strategy also reduces gaseous and particulate emissions associated with gas combustion, including small amounts of criteria pollutants such as NO_x, SO_x, $PM_{2.5}$, and VOCs that are ground-level ozone precursors. Energy savings can also be expected from the implementation of gas efficiency measures.

Economic benefits and costs

As with electric energy, investment in gas energy efficiency results in positive economic impacts because of the creation of manufacturing and installation jobs. Further positive benefits result from increased household and commercial sector spending that is due to realizing savings on the gas bill. Negative impacts will result from the lost opportunity costs of investment and the impacts to power generators from lost revenue. Pennsylvania's large natural gas sector will experience negative economic impacts as a result of lower natural gas consumption, but the negative impacts are offset by the positive impacts. The NPV of this strategy is $7.35 billion. Average annual GSP is estimated at -$55.79 million, largely because of fossil fuel impacts. Annual average DPI impact is estimated at $143.77 million resulting from bill savings associated with energy efficiency. The average annual employment impact is expected to be 1,396 jobs.

[36] New York State. Establishing a Value of Carbon Guidelines for use by State Agencies. Accessed April 4, 2021. https://www.dec.ny.gov/docs/administration_pdf/vocfguid.pdf.

Social benefits and costs

The implementation of gas energy efficiency improves air quality by reducing emissions from the combustion of natural gas. This strategy also provides a benefit to public health by directly reducing air pollutants that affect health.

Implementation Considerations

Improving residential and commercial gas efficiency through incentive and retrofitting programs is well established in Pennsylvania and nationally. Changes recommended by this strategy can be implemented immediately and will grow over time. This strategy consists of two main programs:

- Create a program similar to Act 129 to require gas utilities to operate gas energy efficiency programs.
- Establish a commercial building energy performance program, as discussed in the previous strategy.

Reducing gas use in buildings can be accomplished through conservation and efficiency measures that result in a variety of environmental, social, and economic benefits. Energy conservation includes behavioral and operational measures and programs, such as changing temperature settings and energy consuming devices, and reducing the operation hours for space conditioning and other systems. Through energy conservation, gas users can achieve instant, albeit small, reductions through changes in how they use systems and buildings. Energy efficiency, which this strategy focuses on, includes improving the operating performance of buildings through a variety of retrofits and interventions such as:

- Building-envelope improvements (e.g., better windows, insulation, and air sealing)
- New and more efficient appliance and equipment
- Changes to heating and cooling systems (e.g., enhanced building controls, high-efficiency boilers, and high-efficiency hot water heaters).

Act 129 does not require natural gas utilities to reduce direct natural gas consumption, but it does ask utilities to voluntarily establish energy efficiency programs. To increase savings, the state legislature would need to require utilities to reduce direct natural gas consumption, establish annual savings targets, and create a program that allows for beneficial energy efficiency to be expanded. Models for statewide natural gas legislation and programming are available in neighboring states, including New York and New Jersey.

As described in Strategy B, a commercial building energy performance program would also have a significant impact on natural gas use, because gas is a primary fuel source of many large commercial buildings. Program measures and their associated natural gas reductions are a significant benefit of such a program.

Rules for program implementation should ensure equitable implementation and include the continuation of specialized low- and moderate-income programs, like those already in place for

Act 129's electricity programs, to ensure that low-income individuals are not financially harmed. Environmental justice or low-income communities would not benefit financially from implementation of this strategy, and careful implementation would be required to avoid increasing financial burdens and disparities on these communities.

Energy efficiency programs have received broad support by policy makers and program stakeholders provided that the programs continue to be cost effective to participating parties. Creating a gas efficiency program similar to the one called for in Act 129 is feasible given the many benefits of doing so, including job growth and cost savings.

D. 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 use to electricity use in existing buildings and electrification of new buildings when there are large natural gas infrastructure costs or when fuel oil is the alternative.

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
-38,178 GWH of electricity (increase)
222,699 Bbtu of gas

Cost or (benefit) per ton of GHG reduced
$501.76/$MTCO_2e$

Net present value
$(12.19 billion)

Average annual gross state product
$(761.45 million)

Average annual disposable personal income
$(504.13 million)

Average annual employment
-5,155 jobs

Environmental benefits and costs

Electrification of buildings will reduce the amount of gas and fuel oil consumed, and as a result this strategy will reduce emissions of CO_2 and other GHG associated with fossil fuel combustion such as CH_4 and N_2O. This strategy also reduces gaseous and particulate emissions associated with fossil fuel combustion, including small amounts of criteria pollutants such as NO_x, SO_x, $PM_{2.5}$, and VOCs that are ground-level ozone precursors. In the early years of implementation, any reduction in carbon, gaseous, or particulate emissions will be partially offset by emissions from the generation of electricity, but as the grid switches to cleaner sources, emissions savings will be more pronounced. Energy savings are not expected from this measure because natural gas and fuel oil reduction will be offset by an increase in electricity use.

Economic benefits and costs

The electrification of residential and commercial sectors is expected to have negative economic impacts. While positive impacts are expected in manufacturing and construction (installation) sectors, costs of electrification are high. Paying for electrification will lower disposable income and expenditures in other consumption categories, resulting in net negative economic impacts. The NPV of this strategy is -$12.19 billion. Average annual GSP and DPI impacts are estimated at -$761.45 million and -$504.13 million, respectively. The average annual employment impact is expected to be -5,155 jobs.

Social benefits and costs

The implementation of electrification measures improves air quality by reducing emissions from the combustion of natural gas and fuel oil. This strategy also provides a benefit to public health by directly reducing emissions that affect health. In the early years of implementation, any reduction in carbon, gaseous or particulate emissions will be partially offset by emissions from the generation of electricity, but as the grid switches to cleaner sources, emissions savings will be more pronounced.

Resilience Considerations

Scaling up electrification may provide a variety of climate resilience benefits and opportunities, such as reduced air pollution and associated public health benefits, which can help combat potential declines in air quality and health associated with higher temperatures. It may also reduce sensitivity to price fluctuation of specific fuels, providing financial benefits. However, given projected increased risk of extreme weather events that may cause power outages, ensuring electricity reliability will be increasingly critical.

Considering opportunities to build redundancy and resilience into the electric grid, such as pairing distributed renewable generation with backup battery storage, developing microgrids or demand side management options, using smart technology to efficiently pinpoint outage locations, and working alongside other public and private actors to ensure the grid is resilient to projected climate conditions will be critical in safely electrifying the Commonwealth.

Implementation Considerations

Electrification incentive programs are growing in popularity in the United States but would be new for Pennsylvania. Program design and incentives could be modeled on those in New York's Clean Heat programs, which aim to implement solar hot water heating and air/ground source heat pumps. Program implementation would require support from a variety of educational programs. Broad electrification is still challenged by its lack of cost-effectiveness and limited customer awareness and confidence in the technologies. Supply chains for heat pump technologies will need to grow, and installation contractors will need to offer a broader set of solutions.

To support market growth, government could pilot the use of heat pump solutions in government buildings, with the goal of growing the market and demonstrating the technologies' use and effectiveness. Cost reductions and gains in technology efficiency are critical to the adoption of electrification. Cold climate air source heat pump technology has advanced significantly in recent years, but costs remain high.[37] A rebate program offered opportunities for implementing electrification solutions in Maine. Heat pumps as a secondary heating source (adjacent to fuel oil, propane, and other fuels) and as a source for air conditioning in the summer have been installed and incentivized.[38] A similar offering could be successful in Pennsylvania buildings without air conditioning and where heat pumps could gain part of the heating market share.

---

[37] NYSERDA, 2019 New Efficiency: New York Analysis of Residential Heat Pump Potential and Economics. https://www.nyserda.ny.gov/-/media/Files/Publications/PPSER/NYSERDA/18-44-HeatPump.pdf

[38] Efficiency Maine, Accessed March 19, 2021. https://www.efficiencymaine.com/heat-pumps/

Eventually, the state legislature could require utilities to implement beneficial electrification solutions, in alignment with the natural gas–reducing strategies outlined in Strategy C. Legislation could establish annual savings targets or create a program that allows for beneficial electrification to be expanded. This work would need to align with Pennsylvania's Act 129, because many of the measures would increase electricity use. Models for statewide legislation and programming are available in neighboring states, including New York.

Equity considerations of beneficial electrification would need to be integrated into the design of a new program. Careful attention to ensuring that low- and moderate-income customers are given opportunities to participate is needed. Electrification measure implementation should also consider resiliency issues because heat pumps and most electrification requires grid electricity to provide heat.

Embodied Carbon Emissions

Embodied carbon emissions consist of the GHGs associated with materials and construction processes throughout the whole lifecycle of the built environment. This document focuses on the mitigation of carbon emissions associated with operational activity happening within the Commonwealth, but the Commonwealth's infrastructure and building construction contain embodied emissions, which should also be considered in decision making. Green building practices typically seek to reduce the footprint of construction by focusing on local and materials with lower lifecycle emissions. In Pennsylvania, green building practices are extremely popular, and programs exist in both Philadelphia and Pittsburgh to support green buildings. Additionally, the PA Department of General Services Bureau of Capital Projects is currently working to require embodied carbon considerations in Commonwealth-owned new construction and major renovation projects. Some regional and sub-national government entities have pursued consumption-based inventories to understand their global carbon impact associated with manufactured goods consumed within the boundaries.

E. Increase distributed on-site solar

This strategy includes the installation of on-site distributed solar in both the residential and commercial sectors. On-site, distributed solar photovoltaics play an important part in the decarbonization of the electrical grid. On-site solar implementation will align with the grid decarbonization strategies outlined in Strategies N and O. To maximize the benefits of this strategy, use of solar must expand across the Commonwealth, legislation enabling development of a robust solar industry at the distributed level must be passed, and strategies that increase the value of solar renewable energy credits (SRECs) must be implemented.

Annual GHG emissions reduced in 2025
296 $MTCO_2e$

Annual GHG emissions reduced in 2050
5,819,168 $MTCO_2e$

Annual energy reduced in 2050
Replaces 21,581 GWH of grid-supplied electricity

Cost/(benefit) per ton of GHG reduced
Included in Strategy O

Net present value
Included in Strategy O

Average annual gross state product
$494.93 million

Average annual disposable personal income
$425.40 million

Average annual employment
5,603 jobs

Environmental benefits and costs

By generating renewable electricity, this strategy reduces emissions of CO_2 and other GHG associated with grid electricity sources such as CH_4 and N_2O. This strategy also reduces gaseous and particulate emissions associated with electricity generation, including criteria pollutants such as NO_x, SO_x, $PM_{2.5}$, and VOCs.

Economic benefits and costs

The installation of on-site distributed solar is expected to have positive economic impacts. Some positive impacts result from growth in manufacturing and installation jobs, as a result of photovoltaic investments, but most of the positive impacts result from bill savings. While there is some initial investment, significant bill savings will accrue over time, resulting in additional cost savings potential in later years. Average annual GSP and DPI impacts are estimated at $494.92 million and $425.40 million, respectively. The average annual employment impact is expected to be 5,603 jobs.

Social benefits and costs

The implementation of distributed on-site solar improves air quality by reducing emissions from grid electricity generation sources. This strategy also provides a benefit to public health by directly reducing emissions that affect health. Distributed on-site solar has the potential to improve the resiliency of infrastructure, because solar paired with battery technology can be used to supply power to buildings in case of emergency power shutoffs or blackouts.

Implementation Considerations

Pennsylvania has already supported a variety of distributed on-site solar installations through a combination of programs and policies that provide financial support, rules, and incentives. Programs such as the PA Sunshine Solar Rebate program have provided a direct rebate to users who installed solar projects, while Pennsylvania's net metering rules have allowed on-site solar projects to be more competitive. And as the installed cost of solar PV projects has declined, the state's Alternative Energy Portfolio Standard (AEPS) has continued to provide financial support to solar projects.

A robust AEPS (as described in Strategy O) will support additional utility and distributed on-site solar projects through a market-based program. Implementation of new distributed solar has been discussed extensively in Pennsylvania's Solar Future Plan,[39] which includes a full set of technology support options, including financing, workforce development, and potential incentives.

Distributed solar projects have several benefits that support the equitable implementation of this strategy. Job creation from distributed solar projects is significant, and solar installers are expected to be a large job-growth area in the coming decade. With its benefits, solar has generally received robust support from the public and policy makers. Implementation of distributed solar also presents an opportunity to enhance resiliency of energy systems when paired with battery or microgrid technologies. As the costs of batteries continue to fall and the deployment of battery technology grows, the possibility for the broad adoption of solar-battery installations has the potential to support the grid. Siting solar projects in underutilized settings such as abandoned fields, brownfields, and warehouses, will help balance carbon sequestration and GHG emission reduction opportunities.

Pennsylvania's Solar Future Plan

In late 2018, DEP published Pennsylvania's Solar Future Plan, a stakeholder-led document that established a target of producing 10% of the Commonwealth's electricity from in-state solar by 2030. The 2021 CAP is aligned with this plan, which saw the following benefits:

- **Jobs:** 60,000 to 100,000+ jobs, depending on the ratio of smaller systems to larger systems. From installers to system designers, these solar jobs have median wages of $20–$38 per hour, and will be available in rural, urban, and suburban areas.
- **Economic development opportunities:** There are opportunities to site solar development in ways that complement the working landscape and rural economy, such as using solar on buffer zones, disturbed lands, and in conjunction with grazing or pollinator friendly perennials.
- **Net benefit of free fuel and cost savings:** The combination of fuel savings (free sunlight) and anticipated cost savings (avoided public health and environmental damages) could result in a net benefit of over $1.60 billion annually from 2018 to 2030.

Resilience Considerations

Increased distributed renewable energy generation may have climate resilience co-benefits. For example, it may reduce the risk of widespread power outages associated with impacts to infrastructure susceptible to damage in extreme weather (e.g., transmission lines, distribution poles) and support demand flexibility, and lower long-term energy costs. Extreme events are projected to occur with increasing frequency and intensity under climate change, and peak power demand may increase as peak summer temperatures get warmer. Without increased resilience and redundancy in the power grid, higher peak demand increases the risk of impacts like higher energy costs for consumers and power outages.

[39] Pennsylvania DEP. Pennsylvania's Solar Future Plan. Accessed April 5, 2021. https://www.dep.pa.gov/Business/Energy/OfficeofPollutionPrevention/SolarFuture/Pages/Pennsylvania's-Solar-Future-Plan.aspx.

Transportation

The transportation sector encompasses all activities that facilitate the transportation of people and goods, while providing a wide range of services. The transportation sector is the second-largest source of GHG emissions in the Commonwealth, and most of these emissions are generated by burning fuel to power internal combustion engines for light-duty passenger cars and trucks. Transportation-related GHG emissions have decreased over the past two decades, however, even as the number of cars on the road and trips taken has increased. This trend is due primarily to higher fuel-economy standards, and is expected to continue as hybrid and zero-emissions vehicles become a significant fraction of vehicles on the road.

In 2018, more than 102 million vehicle miles were traveled in Pennsylvania.[40] Transportation is vital to Pennsylvania's economy, contributing in 2015 an estimated $1.3 billion to the local economy and employing more than 182,000 people. There are more than 120,000 miles of roads, 22,000 bridges, 5,127 miles of railroad tracks, and more than 400 airports in Pennsylvania.[41]

Transportation activities and related emissions are projected to increase in the next decades according to the BAU scenario that reflects the current trends of a growing population in and around urban centers, and more miles driven per capita.

Transportation and Climate Initiative

- The Transportation and Climate Initiative (TCI) is a regional collaboration of 13 Northeast and Mid-Atlantic states and the District of Columbia that seeks to improve transportation, develop the clean energy economy and reduce carbon emissions from the transportation sector.
- TCI-P is a cap and invest program. It builds on and can work with other options for reducing emissions from the transportation sector.
- DEP supports the development, outreach, and engagement of the program. Pennsylvania is not currently participating in TCI-P.

The strategies proposed to address transportation emissions reflect current technological and policy trends of lower fuel consumption and lower carbon intensity of the fuel consumed. Taken together, these two approaches can significantly lower GHG emissions and other air pollutants originating from tailpipes. Four strategies are modeled:

- Increase fuel efficiency of all light duty vehicles and reduce vehicle miles traveled for single occupancy vehicles.
- Implement the multistate medium- and heavy-duty zero-emission vehicle memorandum of understanding (MHD ZEV MOU), of which the Commonwealth is a signatory.
- Increase adoption of light-duty electric vehicles.

---

[40] EIA, 2021. "Pennsylvania State Profile and Energy Estimates." https://www.eia.gov/state/data.php?sid=PA.

[41] American Road and Transportation Builders Association. N.d. "Pennsylvania Transportation Facts—Economic Impacts. https://www.artba.org/wp-content/uploads/2016/08/econ_profile_2015_Pennsylvania.pdf.

- Implement a low carbon fuels standard (LCFS).

The modeling results indicate that these strategies will reduce emissions compared to the BAU scenarios in 2025 and 2050 (Figure 26), and in 2050 will reduce emissions in the transportation sector by 33,989,502 MTCO_2e (Table 4).

For each strategy, the environmental, economic, and social benefits are reported, along with the costs (or savings) associated with the implementation of the strategy. The environmental benefits and costs (or savings) are expressed in terms of GHG emission reductions and changes in energy and fuel use. For the strategies that rely on switching from conventional engines to electric vehicles, the costs associated with electricity consumption for vehicle charging are included; GHG emissions that come from the additional electricity generation for vehicle charging, however, are not included here, but in electricity generation.

The economic impacts are expressed in terms of change in job numbers, disposable income, and GSP. The social benefits and costs (or savings) are expressed in terms of impact on air quality (e.g., change in criteria pollutants) and associated public health and social impacts such as equity and resilience.

Figure 26. Transportation GHG emissions with reduction strategies compared to business as usual

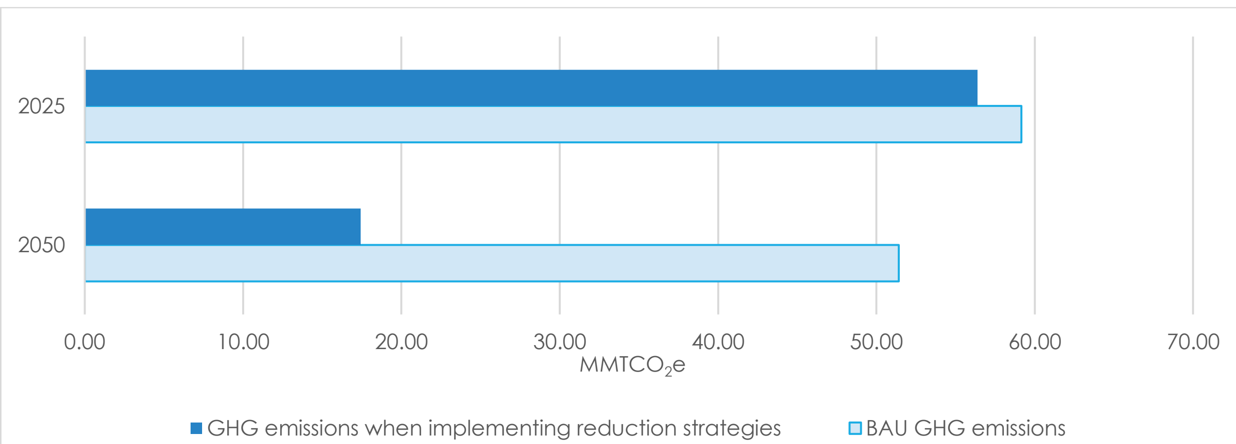


Table 4. Transportation sector GHG reduction strategies and associated reductions (MTCO_2e)

GHG Reduction Strategy	2025	2050
F. Increase fuel efficiency of all light-duty vehicles and reduce vehicle miles traveled for single occupancy vehicles	571,524	2,805,452
G. Implement the multi-state medium-and heavy-duty zero-emission vehicle memorandum of understanding	291,395	7,384,410
H. Increase adoption of light-duty electric vehicles	1,225,113	23,799,640
I. Implement a Low Carbon Fuel Standard	683,365	0*
Total GHG Reductions	**2,771,397**	**33,989,502**

**The carbon intensity goal is achieved by 2050 (due to electrification from other transportation strategies) so there is no additional reduction expected in 2050.*

F. Increase fuel efficiency of all light-duty vehicles and reduced vehicle miles traveled for single-occupancy vehicles

This strategy models a reduction of vehicle miles traveled (VMT) for single-occupancy vehicles by implementing travel-demand solutions such as shifting travel mode choice, making travel more efficient, and increasing telecommuting. VMT reduction efforts are paired with land-use and development policies that promote and incentivize sustainable transportation modes (e.g., walking, biking, transit) in densely populated urban areas and assume the expansion of options for sustainable mobility to and from urban centers (bus rapid transit, carpool) in the medium and long terms.

The analysis uses VMT reduction targets of 3.4% by 2030 and 7.5% by 2050 compared to BAU. This estimate is based on the Pennsylvania Energy Assessment Report of 2018,[42] 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.[43] It also incorporates projected gains in fuel economy for light-duty vehicles, assuming a 20% fuel efficiency increase between 2026 and 2050.

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
39,280 BBtu of fuel

Cost or (benefit) per ton of GHG reduced
$(448.43)/$MTCO_2e$

Net present value
$20.03 billion

Average annual gross state product
$116.51 million

Average annual disposable personal income
$86.38 million

Average annual employment
823 jobs

Environmental benefits and costs

This strategy reduces the amount of fuel consumption by 39,280 BBtu in 2050 (with 98.5% of the fuel being gasoline). The associated GHG emission reductions amount to 571,524 $MTCO_2e$ in 2025 and to 2,805,452 $MTCO_2e$ in 2050. The economic benefits include monetary savings of $448.43 per $MTCO_2$ eliminated, with an NPV of $20.03 billion.

VMT reduction and higher fuel economy reduce additional gaseous and particulate emissions from tailpipes, including criteria pollutants such as NO_x (980 MT of NOx reduction in 2050), SO_x (20 MT of SO_x reduction in 2050), and $PM_{2.5}$, as well as VOCs that are ground-level ozone precursors.

Economic benefits and costs

Reducing vehicle pollution generates immediate improvement in air quality and leads to a healthier environment over time. These changes bring economic benefits directly stemming

[42] DEP 2018. Energy Assessment Report for the Commonwealth of Pennsylvania.
[43] FHWA. 2018. Forecasts of Vehicle Miles Traveled, Spring 2018. Accessed July 3, 2018. https://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_forecast_sum.pdf.

from improvements in public health, such as reduced expenses related to asthma and other respiratory and cardiovascular diseases linked to exhaust from vehicles.

Additional economic benefits of reduced private vehicle use are expected from lower fuel and vehicle maintenance costs, which over time result in higher disposable income for consumers. The strategy is projected to generate $878 million of savings in fuel costs and $1.27 billion of savings in vehicle maintenance in 2050, with a public expenditure of $267 million.

Net economic impacts are expected to be positive. The positive impacts are driven largely by fuel savings associated with less travel, which positively impacts consumer budgets (less money spent on gasoline means more money for other purchases). With less vehicle travel, however, comes less spending on gasoline and vehicle repairs and maintenance. Gasoline stations, rest stops, and repair shops are expected to see negative economic impacts. Increasing fuel efficiency for light-duty vehicles and reducing VMT are expected to have positive impacts on average annual GSP and DPI, expected at $116.51 million and $86.38 million, respectively. The average annual employment impact is expected to be 823 jobs.

Social benefits and costs

Reducing single-occupancy vehicle travel while opting for more sustainable transportation modes reduces road congestion, leading to safer streets and a more pleasant environment for all travel modes. It also improves equity by directly reducing vehicle emissions that disproportionately affect communities living near major roads and highways. Shifting to biking and walking, in particular, creates additional positive health outcomes by increasing exercise opportunities and reducing the stress related to traffic congestion.

Resilience Considerations

Increased fuel efficiency leads to cost savings. Depending on a household's financial situation, these cost savings could be significant, particularly if day-to-day costs may be rising due to impacts of other climate hazards (e.g., higher energy costs of more air conditioning due to warmer temperatures).

Implementation Considerations

A significant VMT reduction can occur only if cost-effective, viable, and convenient transportation alternatives to driving are offered. Because personal mobility needs vary greatly, depending on geographic location, occupation, and demographics, solutions must be tailored to meet different needs. In general, increasing public transit options and the frequency of service encourages travel mode switch. In urban areas, dedicated bus or shared bus/bike lanes are usually effective solutions and are well received by the public because they improve transit service and offer a safer biking environment. Offering micro-mobility options (e.g., bike share) to fill last-mile gaps is also critical to providing access to public transit. Another critical action for the success of this strategy is to build capacity to move people along major commuting routes, either through public transit or private options (e.g., commuter shuttle or vanpool services offered by private companies and large employers).

The actions require coordinated planning and investment, and in some cases, additional infrastructure, therefore the implementation timeframes are considered long. Quick gains, can be achieved, however, especially in urban areas where bus routes and networks can be optimized and redesigned in a few months to a year's time. Similarly, pedestrian and biking experiences can be improved relatively quickly and cost-effectively in urban areas through the creation of bike lanes and the installation of bike-sharing stations. Interventions such as the full implementation of bus rapid transit corridors can take longer.

Depending on the type and scale of the intervention, required funding, and entity overseeing the right-of-way, a VMT strategy might involve different levels of government, from municipality to regional metropolitan planning organizations (MPO), to the state. Small projects such as the separation of bike lanes or the creation of bike share stations can often be planned and resolved at the municipal level; dedicated bus lanes and route adjustments require collaboration between municipalities, transit agencies, and the state DOT. Challenges to implementing these strategies can vary as well and include funding availability (especially for larger interventions), policy acceptance, and consumer behavior. Given the personal nature of transportation, strategies that address VMT reduction also require education, outreach, and community involvement to ensure that all stakeholder voices are heard. The risk of VMT reduction policies stalling is high if they are not accompanied by a robust engagement process and a clear plan. Equity aspects need to be evaluated as well: for example, improving public transit options often directly benefits LMI individuals, who are statistically more likely to use transit or to work jobs that have rigid schedules and are more affected by peak hour congestion.

As more states look at reducing VMT as a win-win strategy for reducing both vehicle emissions and road congestion, policy solutions and enabling technologies will also become more readily available. Those include the targeted use of autonomous electric vehicles, congestion fees, and zero-emission or pedestrian-only zones, especially in densely populated urban centers.

G. Implement the multistate medium-and heavy-duty zero-emission vehicle memorandum of understanding

This strategy models the implementation of the multistate medium- and heavy-duty zero-emission vehicle memorandum of understanding (MHD ZEV MOU), of which the Commonwealth is a signatory.[44] The goal of the MOU is to reach net-zero emissions from new MHDVs by 2050. The strategy assumes that 30% of new MHDV sales will be ZEV by 2030. By 2050, all new MHDV sales are assumed to be ZEV.

Environmental benefits and costs

The MOU implementation reduces the amount of fuel oil consumption by almost 92,000 BBtu in 2050 (where 99% of the fuel is distillate oil). The associated GHG emission reductions amount to 291,395 $MTCO_2e$ in 2025 and to 7,384,410 $MTCO_2e$ in 2050. However, the need to charge battery electric vehicles increases electricity consumption over time to 6,132 GWh in 2050. The strategy leads to savings of $13.06 per MT of CO_2 eliminated, with a lifetime NPV of -$14.12 billion.

The modeling indicates that converting conventional MHDV to ZEV eliminates 18,250 MT of NO_x in 2050 and 78 MT of SO_x in 2050, in addition to other criteria pollutants and VOCs that are ground-level ozone precursors.

Economic benefits and costs

The transition from combustion to electric heavy-duty vehicles leads to a healthier environment and immediate public health improvements in areas that are affected by heavy-duty vehicle traffic. At the same time, the additional electricity generation required for vehicle charging could lead to negative health and environmental outcomes for communities located near power plants (the net impacts will depend on how quickly electricity generation switches from fossil to clean sources).

Annual GHG emissions reduced in 2025
291,395 $MTCO_2e$

Annual GHG emissions reduced in 2050
7,384,410 $MTCO_2e$

Annual energy reduction or increase in 2050
91,888 BBtu of fuel reduction

6,132 GWh of electricity increase

Cost or (benefit) per ton of GHG reduced
$180.27/$MTCO_2e$

Net present value
$(14.12 billion)

Average annual gross state product
$(248.61 million)

Average annual disposable personal income
$(459.56 million)

Average annual employment
-830 jobs

The MHD ZEV MOU is projected to generate fuel savings of $1.06 billion and vehicle maintenance savings of $2 billion in 2050, while the expected capital expenditure from the strategy implementation is $234 million (assuming that MHD ZEV prices decrease 30% by 2030 and 50% by 2050[45]). These results, however, are based on the limited cost data currently available, given the early stage of MHD ZEV deployment. However, examples of new clean

[44] Multi-state Medium- and Heavy-Duty Zero-Emission Vehicle Memorandum of Understanding. https://ww2.arb.ca.gov/sites/default/files/2020-07/Multistate-Truck-ZEV-Governors-MOU-20200714.pdf.

[45] Comparison of Medium- and Heavy-Duty Technologies in California. ICF-Truck-Report_Final_December-2019.pdf (caletc.com)

technology deployment (e.g., solar PV, wind energy) have demonstrated that manufacturing and implementation costs tend to fall much faster than typically predicted. In addition, the current trajectory of light-duty EV prices suggests that the cost of MHD ZEVs might decrease quicker than predicted as adoption becomes more mainstream and manufacturing at scale makes the strategy progressively more cost-effective.

Finally, new local employment opportunities are expected due to the need for installing, operating, and maintaining the necessary ZEV charging infrastructure. The switch to ZEV will, however, cause a reduction of conventional vehicle maintenance jobs and will require retraining of the workforce to maintain overall job numbers.

The macroeconomic impacts of the transition from combustion to electric heavy-duty vehicles are expected to be negative. Investments in vehicles and charging infrastructure will generate employment in both the manufacturing and installation sectors, and the switch from fossil fuels to electricity is also expected to result in bill savings. Expenditures on EVs, losses to the maintenance and repair sectors, and disinvestment in fossil fuels, however, will result in negative economic impacts. In aggregate, the negative economic impacts outweigh the positive ones. Average annual GSP and DPI impacts are expected to be -$248.61 and -$459.56, respectively. Average annual employment impact is expected to be -830 jobs.

Social benefits and costs

This strategy is expected to yield overall improvement in human health due to the direct elimination of tailpipe emissions from conventional MHD vehicles that typically burn diesel fuel, a known source of black carbon and toxic gases. It will also improve equity by directly reducing diesel vehicle emissions that disproportionately affect disadvantaged communities living near highways and commercial and industrial areas. Another significant effect will be the reduction of waste associated with the maintenance of conventional vehicles such as engine oil and other fluids.

Implementation Considerations

This target would be achieved through a mix of fuel-switching to electric and other zero-emission vehicles such as fuel cell electric vehicles. Several MHDV types can be targeted by this strategy, including buses (both transit and school buses), commercial vans, and short- and long-haul trucks. Zero-emission applications in the transit sector are already well underway, with almost 2,800 electric transit buses on the road or on order nationwide at the end of 2020.[46] The electric school bus market is also growing quickly, with a few hundred units already deployed nationwide and potentially thousands being delivered by 2030.[47] In other sectors, such as

---

[46] CALSTART, Zeroing in on the ZEBs. https://calstart.org/wp-content/uploads/2021/01/Zeroing_In_on_ZEBs_FINALREPORT_1262021.pdf

[47] Sustainable Bus. 2020. "Electric school buses in the US: 27,000 units to be built in ten years," Interact Analysis forecasts. https://www.sustainable-bus.com/news/electric-school-buses-us-27000-units-to-be-built-in-ten-years/.

commercial deliveries, ZEV applications are still at the pilot stage but are increasing. Potential actions, as stated in the MOU, may include:

- Financial vehicle and infrastructure incentives
- Nonfinancial 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

The timeframe for implementing this strategy spans several years, and the speed at which the strategy can be implemented depends on how fast the actions listed above can occur. Market forces will also be critical as manufacturers will have to provide vehicles that can satisfy the MHD ZEV MOU requirements. Collaboration among local and state agencies (DEP, DOT, public transit agencies) and local utilities will also be crucial for the MOU implementation.

The early stages of implementation will rely heavily on planning and securing funding for vehicles and charging infrastructure. Identifying cases for pilot studies by partnering with early adopters may be possible. Taking cues from other states that have initiated this process (e.g., California), pilot projects with companies that operate heavy-duty vehicles in port areas appear ideal for trying new MHD ZEV technology because of their relatively low daily mileage and fixed routes. Similarly, urban delivery applications could be targeted for strategic early deployment of MHD ZEV that are already commercially available.

There are strong public health and equity implications from the implementation of the ZEV MOU. Targeting heavy-duty diesel vehicles that operate in disproportionately polluted areas such as ports or delivery hubs can significantly improve the quality of life for frontline communities, which are often low-income and/or minority communities. Likewise, deploying zero-emission delivery options in dense residential neighborhoods, or rolling out electric school buses at scale, can have a significant positive impact on the quality of life of communities across the state.

H. 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. Assuming a moderate EV adoption scenario from the Pennsylvania Electric Vehicle Roadmap,[48] the modeling assumes that electric vehicles will represent 20% of the light-duty market share by 2030, rising to 70% by 2050.

Annual GHG emissions reduced in 2025
1,225,113 $MTCO_2e$

Annual GHG emissions reduced in 2050
23,799,640 $MTCO_2e$

Annual Energy Reduction or Increase in 2050
331,996 BBtu of fuel reduction
33,178 GWh of electricity increase

Cost or (benefit) per ton of GHG reduced
$107.15/$MTCO_2e$

Net present value
$(27.35 billion)

Average annual gross state product
$960.00 million

Average annual disposable personal income
$357.13 million

Average annual employment
5,797 jobs

Environmental benefits and costs

The fuel consumption associated with the strategy decreases by almost 332,000 BBtu in 2050 (98.5% of this value is represented by gasoline fuel). The associated GHG emission reductions amount to 1,225,113 $MTCO_2e$ in 2025 and to 23,799,640 $MTCO_2e$ in 2050. However, electricity consumption required for vehicle charging increases to 33,178 GWh in 2050.

The estimated implementation costs are $107 per MT of CO_2 eliminated, with a negative NPV of approximately -$27.3 billion. However, as the price of batteries decreases and more manufacturers bring EVs to market in the next two to three years, the costs of implementing this strategy will likely be lower than predicted today. Gasoline phase-out targets, like those adopted by California and Massachusetts, to end the sale of gasoline vehicles by 2035 could accelerate the market and reduce overall costs even further.

Finally, the modeling indicates that converting conventional light-duty vehicles to ZEV eliminates 8,293 MT of NO_x in 2050, 180 MT of SO_x in 2050, and other criteria pollutants and VOCs that are ground-level ozone precursors.

Economic benefits and costs

By reducing vehicle pollution, this strategy can generate immediate improvement in air quality and lead to a healthier environment. However, regions that are affected by power plant pollution might see a slightly negative impact from air pollutants associated with the additional electricity generation required for vehicle charging. The resulting net emissions will depend on how fast the power sector displaces fossil fuels, underscoring the interconnectedness of GHG reduction strategies, and the importance of grid decarbonization.

---

[48] DEP. 2019. *Pennsylvania Electric Vehicle Roadmap*. https://cadmusgroup.com/wp-content/uploads/2019/02/PAEVRoadmap.pdf?hsCtaTracking=5ecd2a08-e3bb-4c32-830f-a73eeb43268c%7C734499cd-191d-4114-94b9-e146eca840ad.

Overall, the projected fuel savings are estimated to be $2.743 billion in 2050 (for a light-duty vehicle, consumer-reported fuel cost savings range from $800 to $1,000 per year[49]) while vehicle maintenance and repair savings are estimated to reach $1.27 billion in 2050. The expected capital expenditure from the strategy implementation is $4.8 billion.

As with the implementation of the MHD ZEV MOU, converting the light-duty vehicle pool to electric will create new employment opportunities at the local level, especially for charging infrastructure installation and maintenance, but will reduce conventional vehicle maintenance and repair jobs; retraining a portion of the workforce will be necessary to avoid net job loss.

The macroeconomic effects of the adoption of light-duty EVs are expected to be positive. Investments in vehicles and charging infrastructure will drive jobs in the manufacturing and installation sectors, while significant bill savings (resulting from gasoline and repair and maintenance savings) will result in more money in consumers' pockets for other expenditures. Although there will be job losses in the fossil fuel industry (resulting from lower gasoline sales) and the vehicle repair and maintenance industry (because EVs require less maintenance than internal combustion engine vehicles), the negative economic impacts are outweighed by the positive ones. Average annual GSP and DPI impacts are expected to be $960.00 million and $357.13 million, respectively. The average annual employment impact is expected to be 5,797 jobs.

Health Benefits of Electric Vehicles

A recent study conducted by the American Lung Association analyzes health benefits associated with the widespread transition to zero-emission transportation technologies. This study projects that within Pennsylvania, widespread adoption of zero-emissions vehicles could result in 2050:

- Premature deaths avoided: 200
- Asthma attacks avoided: 2,400
- Work loss days avoided: 10,800
- Avoided health impact costs: $2.37 billion

Source: American Lung Association. 2020. The Road to Clean Air: Benefits of a Nationwide Transition to Electric Vehicles. Available at: https://www.lung.org/getmedia/99cc945c-47f2-4ba9-ba59-14c311ca332a/electric-vehicle-report.pdf.

Social benefits and costs

Vehicle electrification is expected to yield an immediate improvement in public health from the elimination of tailpipe emissions and long-term benefits from GHG reduction. It also improves equity by directly reducing vehicle emissions that disproportionately affect disadvantaged communities living near highways. Waste is also reduced because less maintenance is required for electric vehicles, which have fewer mechanical parts and engine and transmission fluids to be disposed of.

[49] Consumer Reports. 2020. Electric Vehicle Ownership Costs: Today's Electric Vehicles Offer Big Savings for Consumers. https://advocacy.consumerreports.org/wp-content/uploads/2020/10/EV-Ownership-Cost-Final-Report-1.pdf

Electric vehicles also increase overall social resilience because they can be used to supply power to buildings in case of emergency power shutoffs or blackouts. Although vehicle-to-home (V2H) and vehicle-to-building (V2B) applications are not widespread yet, they are being piloted to determine the best business models and are expected to increase. In fact, most of the light-duty EVs coming to market before 2025 (including pickup trucks) will have two-way charging capabilities, and grid interconnection regulations are being considered by public utility commissions and departments of public utility.[50]

Implementation Considerations

Light-duty electric vehicle technology is well established, and the market is accelerating as manufacturing and battery costs go down. But electric vehicle adoption has not reached mainstream yet, and the implementation of this strategy will require intervention in several policy areas as well as technical and financial support. The 2019 Pennsylvania Electric Vehicle Roadmap offers a viable starting point, as it identifies a series of strategies that can be implemented in the short, medium, and long terms. Further, the state is evaluating a rulemaking to become a ZEV state by joining the Advanced Clean Car program.[51] The biggest advantage of the ZEV Program is the possibility to develop a more robust EV market by providing a stable policy and business environment to vehicle manufacturers and car dealerships, which in turn can encourage utilities and other stakeholders to promote and accelerate EV adoption. Monetary incentives and other price-based policies that can be unlocked under the ZEV program will also be key for the success of this strategy. Point-of-sale vouchers, consumer rebates for charging infrastructure, increased public charging availability, and favorable electricity time-of-use rates can have a significant impact on increasing consumer confidence and acceptance of EVs. Nonmonetary incentives such as access to high occupancy vehicle (HOV) lanes or to priority or free parking spaces can also have a beneficial impact.

Resilience Considerations

As described in Strategy D. Incentivize building electrification, scaling up electrification—whether in buildings or vehicles—may provide a variety of climate resilience benefits, such as public health benefits or reduced sensitivity to price fluctuation of specific fuels. At the same time, with the increased risk of extreme weather events projected, which may cause power outages, ensuring electricity reliability will be increasingly important, especially if it coincides with a need to move large numbers of people (e.g., evacuations). Considering opportunities to build redundancy and resilience into the electric grid will be key to safely electrifying the Commonwealth.

To implement this strategy at scale and equitably, DEP could leverage the AFIG Alternative Fuel Vehicle (AFV) Rebate and the Driving PA Forward programs to expand the scope of or create new ad hoc initiatives targeting rural and low-income communities, multifamily building units, workplaces, and private businesses. Initiatives can be designed to also increase access to

---

[50] California Energy Commission. Vehicle to Grid Integration Roadmap. https://www.energy.ca.gov/programs-and-topics/programs/california-vehicle-grid-integration-roadmap-update

[51] California Air Resources Board, Advanced Clean Cars Program. https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program

EVs and other clean mobility options through, for example, the creation of carshare and bikeshare programs that use EVs. Carsharing is a cost-effective way to implement EVs in disadvantaged communities that often struggle with good mobility options, cannot afford private EVs, and perceive EV charging options as a gateway to gentrification and displacement. In these cases, working with community-based organizations that are trusted by residents can help find equitable solutions that fit mobility needs.

Possible challenges to implementing the strategy include lack of political will in passing legislation to encourage or incentivize ZEV adoption, economic challenges to secure funding for incentives, and regulatory delays that can slow down the deployment of charging infrastructure. To overcome regulatory delays, a growing number of cities are implementing local EV readiness ordinances through zoning and land use codes, while streamlining the permitting and compliance processes to reduce delays and unexpected costs.

Finally, consumer education and outreach are critical to addressing the anxiety that some consumers have about EV range and performance. Marketing campaigns and outreach strategies that rely on peer-to-peer learning and sharing of personal experiences have demonstrated to be effective.

I. Implement a low carbon fuel standard

The Low Carbon Fuel Standard (LCFS) is a market-based, fuel-neutral program designed to reduce the carbon intensity of traditional transportation fuels through a system of credits that can then be sold to regulated entities (such as importers, producers, and refiners of petroleum fuels that are required to reduce the carbon intensity of the transportation fuels they sell in-state). Users and producers of low carbon transportation fuels earn LCFS credits through the emission reductions generated by operating zero- or low-emission vehicles. In Pennsylvania, an LCFS-like strategy could expand on the ethanol and biodiesel requirements already in place and include zero-emission vehicles. While the LCFS is fuel neutral, ZEVs generate the highest LCFS credits by achieving the greatest carbon reduction compared to conventional and alternative fuels.

The modeling assumes 12% carbon intensity reduction by 2030, and 22% reduction by 2040. After 2040, no additional GHG reductions through LCFS are modeled, as the carbon intensity goal is achieved by 2050 due to electrification from other transportation strategies. This measure assumes that supporting policies will be implemented to encourage fuel switching and increased electric vehicle adoption required to meet the 2050 carbon intensity targets.

Annual GHG emissions reduced in 2025
683,365 $MTCO_2e$

Annual GHG emissions reduced in 2050[a]
0 $MTCO_2e$

Cost or (benefit) per ton of GHG reduced
$389.57/$MTCO_2e$

Net present value
$(10.02 billion)

Average annual gross state product
$(483.60 million)

Average annual disposable personal income
$(135.33 million)

Average annual employment
-2,514 jobs

[a] The carbon intensity goal is achieved by 2050 due to electrification; therefore there are no additional reductions from this strategy in 2050.

Environmental benefits and costs

The implementation of an LCFS strategy yields GHG emission reductions of 683,365 $MTCO_2e$ in 2025 (in 2040, annual emissions reduced through the LCFS are projected to be 1,584,462 $MTCO_2e$ through the elimination of 26,051 BBtu of distillate fuel oil). Overall, the strategy eliminates 585 MT of NO_x and 16 MT of SO_x in 2040, in addition to $PM_{2.5}$, and VOCs that are ground-level ozone precursors. The LCFS costs $389.57 per $MTCO_2e$ eliminated, with a negative NPV of approximately -$10.02 billion. Compliance costs are estimated to be $511 million.

Although alternative fuels coming from renewable and biological sources reduce GHGs when compared to conventional fossil fuels, concerns remain about the environmental impact of renewable fuel and biofuel in terms of lifecycle GHG emissions from land use. Likewise, although alternative fuels generally reduce gaseous and particulate emissions, biofuels tend to have slightly higher NO_x emissions than diesel or gasoline.

Economic benefits and costs

Alternative fuels are generally associated with improved air quality when compared to gasoline and diesel. Renewable and biofuels are associated with lower energy costs and increased employment opportunities, if produced locally, but costs and other economic benefits vary widely depending on the type of fuel and where and how it is produced. Fuels that can be produced locally reduce reliance on foreign fossil fuels and increase overall energy resilience.

The macroeconomic impacts of an LCFS are expected to be negative. Fossil fuel producers and consumers are expected to see increased costs under an LCFS. Although renewable-fuel producers will see an increase in revenue through the sale of credits, these positive impacts are outweighed by the passing on of these costs to the fossil fuel industry and ultimately the consumer. Average annual GSP and DPI impacts are expected to be -$483.60 million and -$135.33 million, respectively. The LCFS strategy is expected to result in an average annual employment impact of -2,514 jobs.

Social benefits and costs

This strategy is expected to yield an immediate improvement in public health because of the direct elimination of tailpipe emissions and long-term benefits from GHG reduction. This strategy also improves equity by directly reducing vehicle emissions that disproportionately affect disadvantaged communities living near highways.

Implementation Considerations

The implementation of an LCFS requires a multistep process, including policy design, approval, and implementation. The timeframe to implement an LCFS policy can be lengthy, depending on both policy complexity and acceptance of a carbon trading scheme.

An opportunity for creating an LCFS policy in Pennsylvania is the upcoming rollout of the Transportation and Climate Initiative Program (TCI-P), the regional cap-and-invest program to curb transportation emissions. In that context, an LCFS scheme could complement policy to strengthen the TCI-P. From a technical standpoint, Pennsylvania can take cues from California, Oregon, and other states that are considering this policy (most recently Washington State) in creating an effective LCFS that can bring environmental benefits while generating revenue to finance clean transportation programs.

Policy acceptance can be increased by making sure that the LCFS benefits are understood by the public and legislators alike, and that elements of equity are incorporated into the programs that would be financed by LCFS credits. To increase policy acceptance, Pennsylvania can leverage its participation in RGGI, a similar market-based mechanism relying on carbon credits to ratchet down emissions from power generation while creating revenue for the state.

Industry

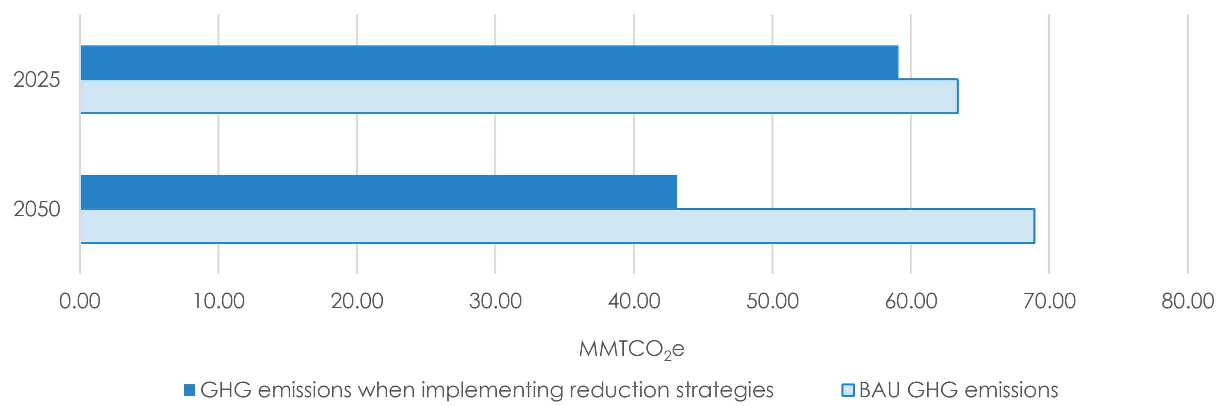
The industrial sector includes GHG emissions associated with industry activities such as physical and chemical material processing and manufacturing. The majority of industrial emissions result from the combustion of fossil fuels to power processes. Other major sources include cement manufacturing, iron and steel production, and the use of ozone-depleting substance (ODS) substitutes. Industrial emissions made up nearly a quarter of Pennsylvania's emissions in 2017, and emissions have remained relatively stable since 2005.

Manufacturing and industry services have historically been the backbone of Pennsylvania's economy, though that role has diminished since the industrial heyday. Key industries in the Commonwealth include metals manufacturing, chemical products, and food processing.[52] Emissions from some of these industrial processes will be difficult to reduce, especially processes such as cement and concrete production that involve chemical reactions that produce emissions that cannot be avoided. Industries with these types of unavoidable emissions could be coupled with CCUS technologies that capture CO_2 emissions and either utilize or sequester the CO_2 to reduce industrial emissions. The phaseout of HFCs is expected to reduce industrial emissions in the future, as are fuel switching and energy efficiency measures.

The strategy proposed to address industrial emissions reflects technological and policy trends that aim to improve energy efficiency and encourage fuel switching. One strategy is modeled: Increase industrial energy efficiency and fuel switching. The modeling results indicate that this strategy will reduce emissions compared to the BAU in 2025 and 2050 (Figure 27), and in 2050 will reduce emissions in the industrial sector by 25,813,870 $MTCO_2e$ (see Table 5).

The environmental, economic, and social benefits of the strategy are reported along with the costs (or savings) associated with the implementation of the strategy. The environmental benefits and costs (or savings) are expressed in terms of GHG emission reductions and changes in energy and fuel use. The economic impacts are expressed in terms of changes in job numbers, disposable income, and GSP. The social benefits and costs are expressed in terms of impacts on air quality (e.g., changes in the criteria pollutants like SO_2, NO_x, and $PM_{2.5}$) and associated public health and social impacts such as equity and resilience.

Figure 27. Industrial GHG emissions when implementing reduction strategies compared to business as usual



[52] EIA, 2021. Pennsylvania State Profile and Energy Estimates. https://www.eia.gov/state/data.php?sid=PA.

Table 5. Industrial sector GHG reduction strategies and associated reductions ($MTCO_2e$)

GHG Reduction Strategy	2025	2050
J. Increase industrial energy efficiency and fuel switching	4,277,761	25,813,870
Total GHG Reductions	**4,277,761**	**25,813,870**

J. Increase industrial energy efficiency and fuel switching

This strategy includes leveraging 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, which was developed by DEP's Energy Programs Office. This strategy would rely on tools such as virtual training and expanded partnerships to reach smaller and hard-to-reach industries. In addition to energy efficiency measures, industrial opportunities that switch from fuel oil to natural gas and measures to switch from natural gas to electricity are included in this strategy.

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

-6,952 GWh of electricity (increase)

407,242 BBtu of gas

Cost or (benefit) per ton of GHG reduced

$64.80/$MTCO_2e$

Net present value

$(21.53 billion)

Average annual gross state product

$(870.15 million)

Average annual disposable personal income

$(519.69 million)

Average annual employment

-804 jobs

Environmental benefits and costs

Energy efficiency and electrification of industrial processes will reduce the amount of electricity, natural gas, and fuel oil consumed, resulting in reduced emissions of CO_2, and other GHG associated with grid sources and combustion such as CH_4 and N_2O. This strategy also reduces gaseous and particulate emissions associated with gas and fuel oil combustion, including criteria pollutants such as NO_x, SO_x, $PM_{2.5}$, and VOCs that are ground-level ozone precursors. For electrification measures, in the early years of implementation, any reduction in carbon, gaseous or particulate emissions will be partially offset by emissions from the generation of electricity, but as the grid switches to cleaner sources, emissions savings will be more pronounced. Even with significant electrification and fuel switching, this strategy is projecting to provide energy savings from electricity, natural gas, and fuel oil.

Economic benefits and costs

This strategy is expected to have negative economic impacts. Although energy efficiency often results in positive economic impacts (generally resulting from energy bill savings), the process of electrification is expensive and may not result in net bill savings. Because of the size of the natural gas industry in PA and the associated fuel costs, using fossil fuel as an energy and heating source is comparatively cheap. The switch from natural gas to electricity does not result in bill savings for electrification, and the bill impacts outweigh the impacts from energy efficiency. Average annual GSP and DPI impacts are expected to be -$870.15 million and -$519.69 million, respectively. The average annual employment impact is expected to be -804 jobs.

Social benefits and costs

This strategy would improve equity by directly reducing emissions that disproportionately affect disadvantaged communities living near point source industrial processes. Poor air quality affects the health of nearly all residents of the Commonwealth, but is more significant for environmental justice communities near industrial plants.

Implementation Considerations

Lowering emissions by improving industrial energy efficiency and pursuing fuel switching has great potential but is one of the more challenging strategies to implement in Pennsylvania and nationally. This strategy consists of technology shifts that prioritize process changes that increase energy efficiency and prioritize a switch to less carbon-intensive fuels. Process and technology changes can be included in the expansion of Act 129 programs discussed in strategies B, C, and D.

Reducing electricity and natural gas in industry can be accomplished through efficiency measures that result in environmental, social, and economic benefits. Energy efficiency, which this strategy focuses on, includes not only improving the overall and operating performance of industrial processes, but also retrofits the buildings that house industrial processes:

- New and more efficient processing equipment
- Lighting retrofits (e.g., LED and other advanced technologies)
- Changes to heating and cooling buildings systems, and process systems (e.g., enhanced controls, high-efficiency boilers, and high-efficiency hot water heaters).

Fuel-switching opportunities can be accomplished through equipment upgrades or infrastructure modifications (such as new gas services) that enable the switch to lower-carbon fuels. Processes that use fuel oils four and six should be targeted for the switch to gas, and low-heat processes and building HVAC processes that use gas should be targeted for the switch to electricity. These switches should be aligned with beneficial electrification processes outlined in Strategy D.

In addition to energy efficiency, energy management techniques and programs can provide energy reduction benefits. The U. S. Department of Energy runs the Better Plants Program,[53] which provides recommendations on operational changes and investment strategies to support more efficient industrial sites. Industrial plants can also seek independent certifications such as ISO 50001 to build and implement an energy management systems approach.[54]

---

[53] U.S. Department of Energy, Better Plants Program. Accessed April 8, 2021. https://betterbuildingssolutioncenter.energy.gov/better-plants/program-information

[54] International Organization for Standardization. Accessed April 8, 2021. https://www.iso.org/iso-50001-energy-management.html

Advances in technology are crucial to achieving carbon reductions in the industrial sector. New equipment and changes to processes have the potential to greatly improve efficiency and reduce carbon. Technology changes vary widely depending on the process, and Pennsylvania's diverse industrial footprint requires innovations across a variety of industrial subsectors. While not specifically modeled, technologies such as hydrogen and other renewable energy generated power-to-gas technologies have outsized potential to reduce emissions. A broad set of stakeholders will need to engage with changing technologies and policy aimed at lowering emissions. Education of stakeholders will be crucial as new lower-carbon technologies demonstrate their proficiency. Financing and access to capital will help deploy solutions more rapidly, as many sites require extensive retrofits to decarbonize their industrial processes.

Fuel Supply

The fuel supply sector includes all upstream activities that deliver fuels to non-electricity-generation end-use points, including production, transportation, and storage activities and fugitive emissions. Pennsylvania has extensive fossil resources, primarily coal and natural gas. Most of Pennsylvania's fuel supply for electricity generation is natural gas (45.2% of net electricity generation in 2020),[55] but the supply of biogas and RNG is growing because coal mines and agriculture, two important sources of biogas and RNG, are abundant in Pennsylvania.

Pennsylvania produced 7 trillion cubic feet of natural gas in 2019, 11 times that produced in 2010. This accounted for approximately 20% of total U.S. natural gas production—only Texas produced more natural gas that year. Pennsylvania exports natural gas to other states in the region, and as internal and external distribution has grown, so has the distribution network. Pennsylvania has 55 underground natural gas storage facilities, more than any other state, and production and distribution are on track to increase further.[56]

The strategies proposed to address fuel supply emissions reflect current technological and policy trends that aim to increase the use of biogas and renewable gas and combined heat and power and to reduce methane emissions. Three strategies are modeled:

- Increase production and use of biogas and renewable gas
- Incentivize and increase use of distributed Combined Heat and Power
- Reduce methane emissions across oil and natural gas systems

The modeling results indicate that these strategies will reduce emissions compared to BAU in 2025 and 2050 (see Figure 28), and in 2050 will reduce emissions in the fuel supply sector by 20,262,763 $MTCO_2e$ (see Table 6).

[55] EIA, 2021. "Pennsylvania State Profile and Energy Estimates." Available at: https://www.eia.gov/state/data.php?sid=PA.

[56] DEP. 2021. Internal data.

For each strategy, the environmental, economic, and social benefits are reported along with the costs (or savings) associated with the implementation of the strategy. The environmental benefits and costs (or savings) are expressed in terms of GHG emission reductions and changes in energy and fuel use. The economic impacts are expressed in terms of changes in job numbers, disposable income, and GSP. The social benefits and costs are expressed in terms of impacts on air quality (e.g., changes in the criteria pollutants like SO_2, NO_x, and $PM_{2.5}$) and associated public health and social impacts such as equity and resilience.

Figure 28. Fuel supply GHG emissions when implementing reduction strategies compared to business as usual

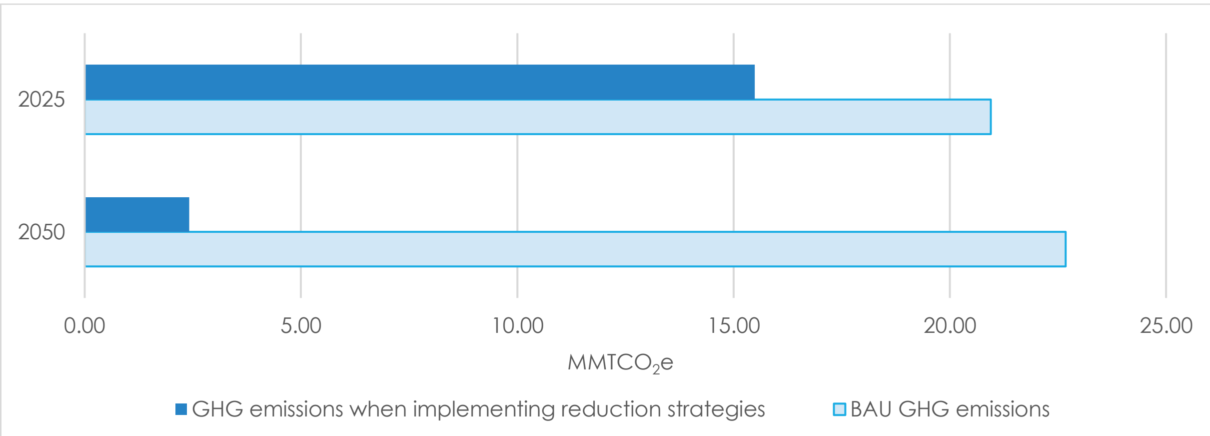


Table 6. Fuel supply sector GHG reduction strategies and associated reductions ($MTCO_2e$)

GHG Reduction Strategy	2025	2050
K. Increase production and use of biogas/renewable gas	1,103,662	10,484,381
L. Incentivize and increase use of distributed Combined Heat and Power	31,279	936,843
M. Reduce methane emissions across oil and natural gas systems	4,320,850	8,841,539
Total GHG Reductions	**5,455,791**	**20,262,763**

K. Increase production and use of biogas/RNG

This strategy involves increasing the production and use of biogas/renewable gas from sources including animal manure, food waste, landfill gas, water resources recovery facilities, agricultural residue, energy crops, forestry residue, and municipal solid waste. This strategy considers the potential for renewable gas and specific applications in Pennsylvania and regionally for a number of feedstocks identified in the 2019 American Gas Foundation RNG report, Penn State University's RNG analysis, and ICF's Pennsylvania RNG database. Some feedstocks for RNG will be used in direct combined heat and power (CHP) applications, although most of the RNG supply will be injected into the pipeline to decarbonize the gas supply in Pennsylvania. The RNG supply increases to 75% of total feedstock by 2050.

Annual GHG emissions reduced in 2025
1,103,662 $MTCO_2e$

Annual GHG emissions reduced in 2050
10,484,381 $MTCO_2e$

Annual energy reduced in 2050
Not calculated

Cost or (benefit) per ton of GHG reduced
$151.40/$MTCO_2e$

Net present value
$(30.23 billion)

Average annual gross state product
$173.74 million

Average annual disposable personal income
$163.11 million

Average annual employment
29,880 jobs

Environmental benefits and costs

Although RNG is chemically similar to natural gas, when combusted, it produces biogenic carbon dioxide, which has a modified impact on emissions because of its biological nature. Thus, the expanded use of RNG will reduce CO_2, CH_4, and N_2O emissions by lowering the amount of natural gas combustion. This strategy replaces 197,326 BBtu of natural gas with RNG in 2050.

Economic benefits and costs

Increasing production and use of RNG is expected to have positive economic impacts. Investments in the RNG sector are expected to spur job growth in the economy. Disinvestment in the fossil fuel sector, however, is expected to drive some negative economic impacts. Overall, net economic impacts are expected to be positive. Average annual GSP and DPI impacts are expected to be $173.74 million and $163.11 million, respectively. This strategy is expected to foster employment for the construction of pipeline interconnections to feed the RNG supply to the natural gas distribution system, resulting in average annual employment of 29,880 jobs. This strategy has a net cost of $151.40 per $MTCO_2e$. Fossil natural gas is cheaper than RNG at present, and as a result this strategy will increase energy costs.

Social benefits and costs

RNG production offers an opportunity to reduce waste by using waste products (e.g., agricultural residue, municipal solid waste) as feedstocks for RNG production. Using waste products as feedstock diverts waste from landfills and produces energy for other uses. This strategy will result in resilience for Pennsylvania's energy supply and infrastructure by decentralizing the supply sources of gas. By increasing the supply from various RNG feedstocks, Pennsylvania will have alternative sources of gas production when fossil natural gas production is disrupted.

Although combusting RNG reduces net GHG emissions and has improved climate benefits compared to burning fossil natural gas, synthetic and biogenic RNG combustion does create local air pollution—emission of VOCs, PM, and CO—similar to that created by fossil natural gas combustion. New policies are needed to decarbonize the gas sector and should also address social costs such as local air quality and health impacts.

Biogenic and Fossil Emissions

When fossil fuels are combusted, carbon that has been stored for millions of years is released and adds to the carbon in our atmosphere. But when RNG is combusted, biogenic carbon is released. Biogenic carbon operates within the natural carbon system and returns to the atmosphere the carbon that was absorbed as plants grew.

Implementation Considerations

This strategy's implementation would begin immediately through use in state of feedstocks that have potential uses for RNG. The technical resource potential of these feedstocks will increase over time, and in 2050, 75% of the collective technical resource potential could be achieved.

Implementation partners include organizations and companies running feedstock operations (e.g., farms), natural gas distribution companies, and regulatory authorities for public utilities, (i.e., Pennsylvania's Public Utility Commission [PUC]). The PUC would be responsible for implementing the strategy, and may consider an RNG portfolio standard to support implementation. A renewable gas portfolio standard would set targets for the use of RNG by Pennsylvania's natural gas utilities and would direct the PUC to establish mechanisms by which the utilities could recover their investments in RNG projects.

There are economic, technical, and social challenges to increasing the RNG supply. First, the capital and operating costs of capturing and cleaning biogas are high, particularly when compared to the low cost of fossil natural gas. Second, maintaining a continuous stream of a feedstock can be a technical challenge to successful CHP operations. There are technical concerns about the varying requirements of gas systems for injection of RNG into a pipeline that can prohibit RNG interconnection, so there is also the cost of developing infrastructure to deliver RNG to customers, although advances in technology can lower these costs. Finally, public perception of RNG includes misconceptions that RNG is less clean or of lower quality than fossil natural gas.

Despite these challenges to increasing the RNG supply, there are solutions that can be explored. A policy solution to advance RNG project development is to establish interconnection incentives and flexible, transparent biogas quality guidelines for pipeline injection.[57]

RNG is produced in a series of steps: collection of a feedstock, delivery to a processing facility for biomass-to-gas conversion, gas conditioning, compression, and interconnection and injection into the pipeline. The most common way to produce RNG today is through anaerobic digestion. For RNG production, anaerobic digestion takes place in a controlled environment

---

[57] EPA. 2021. An Overview of Renewable Natural Gas from Biogas. https://www.epa.gov/sites/production/files/2021-02/documents/lmop_rng_document.pdf.

called a digester or reactor. In the digester, microorganisms break down organic material over time (a matter of days). The gaseous products of that "digestion" contain a large fraction of methane and carbon dioxide, sometimes referred to as biogas. The biogas is subsequently upgraded and conditioned to yield biomethane, which is injected into the common carrier pipeline.[58]

The thermal gasification of biomass also produces RNG. Thermal gasification includes a broad range of processes whereby a carbon-containing feedstock is converted into a mixture of gases referred to as synthetic gas or syngas, including hydrogen, carbon monoxide, steam, carbon dioxide, methane, and trace amounts of other gases. Thermal gasification generally occurs at high temperatures, which vary depending on the gasification system and the feedstock. RNG can also be produced using renewable electricity as a feedstock to generate hydrogen by way of electrolysis, which is methanated for subsequent injection into the distribution pipeline. This process is referred to as power-to-gas (P2G).

[58] American Gas Foundation. 2019. Renewable Sources of Natural Gas. https://gasfoundation.org/wp-content/uploads/2019/12/AGF-2019-RNG-Study-Full-Report-FINAL-12-18-19.pdf.

L. Incentivize and increase use of distributed combined heat and power

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. High-value applications are those with critical power requirements that can operate CHP systems continuously and are able to utilize all the available electricity and thermal energy. This maximizes the operational efficiency, emission reductions, and resiliency benefits associated with the CHP installations. Critical infrastructure and industrial facilities meet these criteria, making them suitable locations for CHP operations. This analysis considers only traditional topping-cycle CHP applications. Other potential CHP applications, such as waste heat-to-power, require a granular, site-by-site analysis and are not considered in this strategy.

Annual GHG emissions reduced in 2025
31,279 $MTCO_2e$

Annual GHG emissions reduced in 2050
936,843 $MTCO_2e$

Annual energy reduced in 2050
8,764 GWH of electricity
-48,906 Bbtu of gas (increase)

Cost or (benefit) per ton of GHG reduced
\$177.93/$MTCO_2e$

Net present value
\$(1.22 billion)

Average annual gross state product
\$78.42 million

Average annual disposable personal income
\$115.89 million

Average annual employment
552 jobs

Environmental benefits and costs

Distributed CHP with microgrids will reduce the amount of electricity consumed and offset some portion of natural gas that is used. This will result in reduced emissions of CO_2 and other GHG associated with grid sources and combustion such as CH_4 and N_2O. Reductions from this strategy also reduce gaseous and particulate emissions associated with combustion, including criteria pollutants such as NO_x, SO_x, $PM_{2.5}$, and VOCs that are ground-level ozone precursors in early years of implementation. As grid electricity gets cleaner, carbon, gaseous and particulate emissions from this measure will increase relative to the zero-carbon grid.

Economic benefits and costs

CHP systems can be configured to operate during grid outages, thus providing energy resilience for host facilities. When properly sized, CHP is roughly 50% more efficient than separate heat and grid power. As a result, CHP produces fewer carbon emissions compared to marginal grid generators. CHP systems can also be an economic investment, producing energy at a lower levelized cost of energy than grid electricity, depending on local electric and gas rates.

The macroeconomic impacts of the increased use of CHP systems are expected to be positive. Positive impacts are driven primarily by investment impacts to the manufacturing and installation sectors, and by energy savings. Average annual GSP and DPI impacts are expected to be \$78.42 million and \$115.89 million, respectively. The increase in CHP use is expected to result in 552 annual jobs.

Social benefits and costs

This strategy will also result in resilience for Pennsylvania's energy systems, allowing for the continued operation of critical facilities, including public services, hospitals, and industrial plants, to remain independent of the power grid in an electricity interruption. Facilities could also provide services to a region when recovering from weather events or outages and provide grid services during normal operations.

Implementation Considerations

Government intervention will be required to foster widespread deployment of resilient CHP-based microgrids at industrial facilities and critical infrastructure (e.g., hospitals, fire stations, police stations, neighborhood centers, and schools). This will come from a combination of incentives for CHP and microgrid installations and direct funding of projects at government facilities and critical community facilities. In addition to the cost test required for CHP to qualify under Act 129, the Pennsylvania PUC could establish further parameters for CHP, such as emissions reductions. Additionally, state and local governments can fund projects to install resilient CHP microgrids at public buildings, ensuring continued operation and offering community refuges during extended utility outages.

The PUC will ensure equitable distribution of funding for utility incentives, although incentives will naturally be limited to facility owners capable of installing CHP systems. Public sector CHP microgrid installations, however, would make resilient community centers in low-income areas the top priority.

There is a great opportunity for CHP installations to contribute to three areas: (1) improving the energy resiliency of critical facilities, (2) improving energy efficiency, and (3) reducing emissions compared to separate heat and grid power. One of the challenges in implementing this strategy is ensuring that natural gas CHP installations are recognized for their emission reduction contributions and their ability to incorporate RNG and/or hydrogen over time for net-zero emissions as the Pennsylvania grid becomes greener. As the supply of RNG and hydrogen increases, new CHP installations can be required to incorporate these fuels.

M. 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 in methane emissions as a co-benefit of the ongoing rulemaking to curb VOC emissions from oil and gas operations.[59] It also includes voluntary mitigation technologies that would be implemented across operations to further reduce methane emissions beyond regulatory requirements. Methane mitigation actions vary in cost, complexity, and reduction effectiveness. Common technologies include the installation of vapor recovery units, routing blowdown gas to flare, replacement of reciprocating rod-packing systems, and implementing leak detection and repair programs.

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 or (benefit) per ton of GHG reduced
$5.02/$MTCO_2e$

Net present value
$(949.84 million)

Average annual gross state product
$(22.30 million)

Average annual disposable personal income
$(17.39 million)

Average annual employment
-78 jobs

Environmental benefits and costs

Methane can be emitted from a variety of sources in oil and gas systems. Fugitive leaks can occur as equipment ages and deteriorates. Some methane is also intentionally vented into the atmosphere for maintenance or safety requirements. Implementing methane mitigation actions will reduce the volume of CH_4 emitted into the atmosphere, improving air quality and supporting public health. This strategy reduces CH_4 by 8,841,539 $MTCO_2e$ in 2050 and results in costs of $5 per $MTCO_2e$.

Economic benefits and costs

The costs and benefits of methane reduction actions depend on the types of technologies implemented. Although all actions require an initial capital investment, certain methane reduction actions, such as the installation of vapor recovery units, allow for the capture of methane gas that would otherwise be emitted into the atmosphere. These technologies result in an additional benefit to operators who can otherwise use or sell the gas and pay for the cost of the technologies over time. Other actions, such as routing blowdown gas to flare, incur additional costs with no economic incentive.

This strategy represents voluntary actions taken to reduce methane emissions, regardless of economic viability to a particular operator. Therefore, the overall cost impact is a function of the

[59] 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.

technologies utilized, the amount of gas captured, and the time required to recoup those investments through the sale of additional captured gas.

The reduction in methane emissions in oil and gas systems is expected to have some small negative economic impacts. Many methane mitigation techniques require up-front investment or cost to implement and require some ongoing incremental upkeep cost. These additional costs result in negative economic impacts. The average annual GSP and DPI impacts are expected to be -$22.30 million and -$17.39 million, respectively. The average annual employment impact is expected to be -78 jobs.

Social benefits and costs

Methane reduction strategies improve air quality by reducing and capturing GHG pollutants before being released to atmosphere. In addition to climate benefits, these mitigative actions promote safety at operating facilities by reducing leakage of the hazardous gas, which is extremely flammable and can cause explosions if leaked into confined spaces. Proper monitoring and better emissions controls help avoid the creation of unsafe conditions.

Implementation Considerations

Implementation of methane reduction technologies at oil and gas facilities is a function of several factors, including regulatory requirements, economic considerations, and technical feasibility.

Pennsylvania has recently shown interest in reducing oil and gas emissions with its Methane Reduction Strategy.[60] New regulations through programs such as this one will reduce emissions by requiring certain sources to be addressed. These requirements can have a direct impact because they generally shorten the time an operator has to decide to implement mitigative actions. Regulatory requirements can also be effective for implementing mitigative actions for certain sources that may not otherwise be cost-effective.

The economic viability of an action can influence an oil and gas operator's interest in implementing voluntary mitigative technologies. Although some actions enable the capture of sales gas that would otherwise be lost to the atmosphere (and thus provide a return on capture-technology investment), other reduction actions, such as increased flaring, impose additional capital and maintenance costs with no return on investment for operators. Facility configuration can also affect the economics of implementing reduction options, as larger facilities may allow for more volume to be captured with marginal impact on overall capital and maintenance costs. This economy of scale decreases the time required to recoup investment, making reduction actions more viable for certain facilities.

---

[60] Pennsylvania Department of Environmental Protection. 2016. *A Pennsylvania Framework of Actions for Methane Reductions from the Oil and Gas Sector.* Available at: https://files.dep.state.pa.us/Air/AirQuality/AQPortalFiles/Methane/DEP%20Methane%20Strategy%201-19-2016%20PDF.pdf

Mitigation actions also depend on the specific on-site operations at each individual facility. The layout and configuration of the equipment can allow or disallow certain actions. Issues such as the spacing or size requirements for reduction equipment sometimes do not allow operators to implement certain actions easily, particularly actions requiring large supporting equipment (i.e., vapor recovery systems).

Electricity Generation

Electricity generation is the greatest source of GHG emissions in the Commonwealth, accounting for nearly 30% of total emissions. GHG emissions from this sector are emitted primarily by burning fossil fuels such as coal and natural gas. Pennsylvania is the third-largest energy producing state in the U.S., after Texas and Florida. Pennsylvania is the third-largest coal-producing state in the nation and second-largest natural gas producer.[61] Pennsylvania is also second in electricity generation from nuclear power.[62] Until recently, coal and nuclear were the predominant fuels for generating electricity in Pennsylvania. However, significant growth in natural gas production, due to technological advances and lower prices, has largely displaced coal-fired electricity generation. As of 2020, natural gas has overtaken nuclear as the largest fuel source for electricity generation in Pennsylvania, and it is expected to provide an increasing share of electricity in future years.

The transition from coal to natural gas, and to a lesser degree, the gradual increase in clean renewable energy sources, has reduced overall emissions from the sector significantly. Decreasing costs of renewable energy technology and enabling policies such as the AEPS have helped drive recent increases in renewable power generation, which in 2020 provided just over 4% of total electricity generation.[63]

The strategies proposed to address electricity generation emissions reflect current technological and policy trends that aim to decarbonize the electricity grid. Two strategies are modeled:

- Maintain nuclear generation at current levels
- Create a carbon emissions-free grid

The modeling results indicate that together these strategies will reduce emissions compared to the BAU in 2025 and 2050 (Figure 29) and in 2050 will reduce emissions in the electricity generation sector by 55,741,567 $MTCO_2e$ (see Table 7).

For each strategy, the environmental, economic, and social benefits are reported along with the costs (or savings) associated with the implementation of the strategy. The environmental benefits and costs (or savings) are expressed in terms of GHG emission reductions and changes in energy and fuel use. The economic impacts are expressed in terms of changes in job numbers,

---

[61] EIA, 2021. "Pennsylvania State Profile and Energy Estimates." Available at: https://www.eia.gov/state/data.php?sid=PA.

[62] EIA, 2021. "Pennsylvania State Profile and Energy Estimates."

[63] EIA, 2021. "Pennsylvania State Profile and Energy Estimates."

disposable income, and GSP. The social benefits and costs are expressed in terms of impacts on air quality (e.g., changes in criteria pollutants like SO_2, NO_x, and $PM_{2.5}$) and associated public health and social impacts such as equity and resilience. Note that costs and savings associated with maintenance, expansion or reconfiguring of either the distribution or transmission grids to manage distributed energy resources and new utility scale renewable projects were not estimated as part of these strategies. Investments for grid modernization will be needed with or without the implementation of reduction strategies.

Figure 29. Electricity generation GHG emissions when implementing reduction strategies compared to business as usual

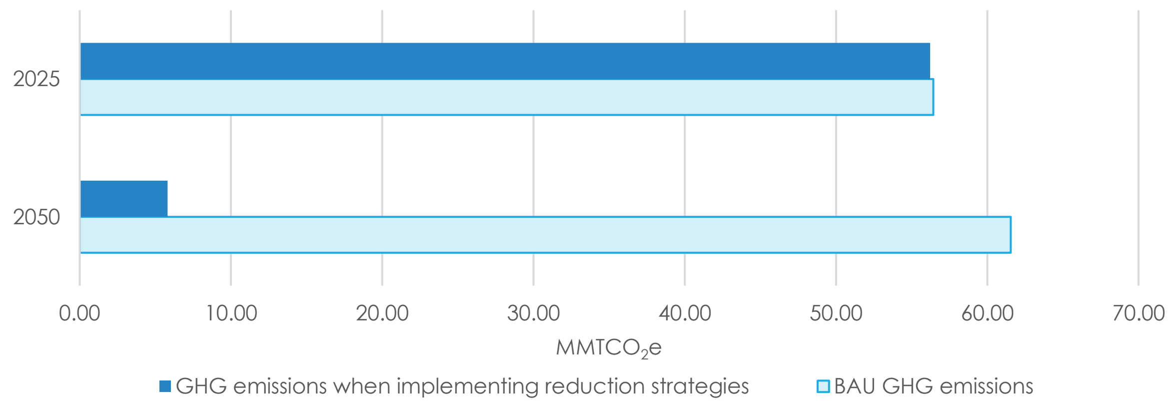


Table 7. Electricity generation sector GHG reduction strategies and associated reductions ($MTCO_2e$)

GHG Reduction Strategy	2025	2050
N. Maintain nuclear generation at current levels	N/A*	N/A*
O. Create a carbon emissions free grid	206,712	55,741,567
Total GHG Reductions	**206,712**	**55,741,567**

**GHG reductions from Strategy N, Maintain nuclear generation at current levels, are included under the carbon-free grid strategy and thus are not reported separately.*

N. Maintain nuclear generation at current levels

This involves implementing a strategy to maintain nuclear generation at current levels. The BAU and 80x50 scenarios assume an 80-year lifetime for all U.S. nuclear units, which would mean that all plants currently in operation will stay online through at least 2050. This strategy assumes that, if needed, Pennsylvania would intervene to keep nuclear units online for their full lifetime, preventing any early retirements. This lifetime assumption is incorporated into the carbon emissions-free grid strategy, Strategy O, and therefore the costs and benefits associated with this strategy are incorporated in the carbon-free grid strategy.

Nuclear facilities can obtain two 20-year operating license extensions from the Nuclear Regulatory Commission; increasing their lifetime to 60 and 80 years. Two facilities have been granted a second extension, known as a subsequent license renewal (SLR): Peach Bottom Units 2 and 3 and Turkey Point Units 3 and 4. These SLRs extend their lifetime to 80 years. There are five SLR applications representing 11 nuclear units (Point Beach Units 1 and 2, North Anna Units 1 and 2, Surry Units 1 and 2, Oconee Nuclear Station Units 1, 2, and 3, and St. Lucie Plant Units 1 and 2) that are pending with the NRC. Only two units in Pennsylvania currently have an 80-year operating license—Peach Bottom 2 and 3. The other six units currently operating in Pennsylvania will have to apply for one or two 20-year renewals to operate for 80 years.

Table 8 lists the current operating nuclear units in Pennsylvania, their current operating license lifetime, and what their retirement year would be, assuming they all receive an SLR extension.

Annual GHG emissions reduced in 2025
Included in Strategy O

Annual GHG emissions reduced in 2050
Included in Strategy O

Annual energy reduced in 2050
Not calculated

Cost or (benefit) per ton of GHG reduced
Included in Strategy O

Net present value
Included in Strategy O

Average annual gross state product
Included in Strategy O

Average annual disposable personal income
Included in Strategy O

Average annual employment
Included in Strategy O

Table 8. Pennsylvania nuclear plants and their lifetimes

Nuclear Plant	Online Year	Operating License Expiration Year	80-yr Lifetime
Beaver Valley Unit 1	1976	2036	2056
Beaver Valley Unit 2	1987	2047	2067
Limerick Unit 1	1985	2024	2065
Limerick Unit 2	1989	2029	2069
Peach Bottom Unit 2	1973	2053	2053
Peach Bottom Unit 3	1974	2054	2054
Susquehanna Unit 1	1982	2042	2062
Susquehanna Unit 2	1984	2044	2064

Environmental benefits and costs

By maintaining current levels of carbon-free electricity and preventing the units from retiring before their 80-year lifetime, this strategy reduces emissions of CO_2 and other GHG associated with fossil electricity sources such as CH_4 and N_2O. This strategy also reduces gaseous and particulate emissions associated with fossil electricity sources, including criteria pollutants such as NO_x, SO_x, $PM_{2.5}$, and VOCs.

Economic benefits and costs

The macroeconomic impacts of maintaining nuclear generation at current levels are combined with the impacts of a carbon emissions-free grid (Strategy O). Macroeconomic impacts resulting directly from this strategy are expected to be negligible.

Social benefits and costs

Maintaining the current nuclear fleet improves air quality by reducing emissions from the grid that would otherwise replace production from nuclear generation if any units retire early—i.e., before the grid is decarbonized. This strategy also provides a benefit to public health by directly reducing emissions that affect health.

Implementation Considerations

Maintaining the current nuclear capacity may require the state to subsidize facilities if they face unfavorable economic conditions. In the electricity strategies, the 100% AEPS and associated solar carve-out put downward pressure on energy prices because of the significant increase in variable renewable energy generation. Assuming status quo energy and capacity market structures, nuclear facilities may face economic pressure and require Commonwealth intervention to ensure that the facilities do not retire early because of lower wholesale market revenues. One intervention the Commonwealth legislature could make is to pass legislation designating a Commonwealth agency to create and administer a Zero Emission Credit (ZEC) program to subsidize at-risk nuclear plants, as states such as New Jersey, New York, and Illinois have done.

Possible challenges to implementing the strategy include lack of political will to secure funding for ZEC incentives and economic challenges. To mitigate economic challenges, the Commonwealth could limit subsidy eligibility to units that can prove that their unfavorable economic conditions are likely to result in the retirement of the unit. This will also benefit ratepayers by limiting the cost of this strategy. Maintaining the Commonwealth's nuclear capacity also provides long-term economic benefits by ensuring that the communities in which they are located continue to receive tax payments and the facilities continue to provide jobs.

After 2050 the nuclear capacity will begin to reach its lifetime of 80 years, and nuclear maintenance programs will be phased out as the units retire. The ability of this strategy to provide consistent and reliable carbon-free power for at least the next 30 years contributes significantly to Pennsylvania's ability to decarbonize its electricity generation. By 2050, replacing the retiring nuclear units with other clean energy resources will be more cost-effective than if the nuclear capacity were to retire early.

O. Create a carbon emissions-free grid

This strategy includes amending and increasing the Alternative Energy Portfolio Standard (AEPS) to an in-state requirement of 100% by 2050 to achieve a carbon-free electricity grid. The electricity grid is the network that generates and delivers electricity to consumers and includes generating stations, electrical substations, and transmission and distribution power lines. Tier 1 targets and the solar carve-out would be increased. The solar carve-out can be supplied by in-state grid-scale and distributed solar resources. Nuclear and fossil energy with carbon capture and sequestration, as well as energy storage, would be added to the definition of eligible energy sources for Tier 1, or a new tier could be created in the portfolio of options to meet the 100% target. The Tier 2 requirement is maintained at the current level of 10% through 2050.

To implement this strategy successfully, additional efforts will be needed, such as strategies to expand the development of solar and wind projects and legislation to help develop a robust solar industry. Increasing the solar carve-out to 10% by 2030 would help increase the value of solar renewable energy credits (SRECs). This aligns with the DEP's Pennsylvania Solar Future Plan, as discussed in Strategy E.

Annual GHG emissions reduced in 2025
206,712 $MTCO_2e$

Annual GHG emissions reduced in 2050
55,741,567 $MTCO_2e$

Annual energy reduced in 2050
Not calculated

Cost or (benefit) per ton of GHG reduced
$46.97/$MTCO_2e$

Net present value
$(50.54 million)

Average annual gross state product
$(658.98 million)

Average annual disposable personal income
$(1.13 billion)

Average annual employment
-5,285 jobs

Environmental benefits and costs

Decarbonizing electricity generation reduces emissions of CO_2 and other GHG associated with fossil electricity sources such as CH_4 and N_2O. As the grid becomes cleaner and less reliant on fossil-based sources of electricity, annual emissions are reduced, and by 2050, emissions are reduced by 55,741,567 $MTCO_2e$—the greatest emissions reduction from any strategy in this CAP.

Economic benefits and costs

The creation of a carbon-free grid will result in both positive and negative economic impacts. Construction of new power generation and storage facilities, particularly utility-scale solar and paired storage, will create many construction jobs in Pennsylvania. Some manufacturing and utility jobs will also result from the construction and will be maintained over the long term for operation and maintenance. The switch to a carbon-free grid, however, will negatively impact the fossil fuel industry in Pennsylvania. Shifting away from coal and natural gas to renewable sources of power will result in job losses. This strategy is expected to result in average annual

GSP and DPI impacts of -$658.98 million and -$1.13 billion, respectively. Additionally, this strategy is expected to result in an average annual employment impact of -5,285 jobs. The macroeconomic impacts of the carbon-free grid strategy reflect the demand changes called for in the energy efficiency and electrification strategies. The costs modeled in this strategy represent the changes in utility scale generation, but not all costs associated with the implementation of distributed energy resources in the distribution grid are included. Many utilities already perform upgrades to distribution grids for storm hardening and resiliency, and costs associated with the integration of distributed energy resources could be included in those investments.

Social benefits and costs

Decarbonizing the power sector improves air quality by reducing emissions from sources of electricity that would otherwise backfill the nuclear generation if any units retire. This strategy also provides a benefit to public health because it reduces gaseous and particulate emissions associated with fossil electricity sources, including criteria pollutants such as NO_x, SO_x, $PM_{2.5}$, and VOCs.

Implementation Considerations

Creating a carbon-free grid will require legislative action to revise the current AEPS. The target of the AEPS will have to be changed to 100% by 2050, with interim targets established. In addition, the solar carve-out will need to be increased, following Pennsylvania's Solar Future Plan, to require 10% by 2030. This could increase over time to maintain SREC pricing. The AEPS eligibility definitions will also need to expand to include nuclear, storage, CCUS, and any future carbon-free technologies that are developed. Implementing AEPS changes would occur through government

Revitalizing Decommissioned Coal Power Plants

Over the last 10 years, coal-fired power has been steadily losing its competitive edge to lower-emitting power generation resources, and Pennsylvania has witnessed the retirement and decommissioning of most of its coal-fired power plants. Although moving away from coal power has helped the Commonwealth reduce its GHG emissions, the local economic impacts to communities that have lost jobs associated with coal can be difficult to deal with. The Pennsylvania DCED has developed "Economic Repositioning Playbooks for Decommissioned Coal-Fired Power Plants" to begin bringing otherwise valuable brownfield properties back into productive reuse for the community. Although they are no longer in use, they offer opportunities to usher in a new generation of development because typically they are near river, road, rail, and energy transmission infrastructure. The contents of each "playbook" are tailored to the unique attributes of a site that need to be evaluated to help spur redevelopment interest. A typical playbook report includes:

- An assessment of potential or existing environmental impacts
- Cost estimates for demolition and abatement of the plant and associated structures
- Identification of existing permits that may be available for a new end user
- An assessment of existing infrastructure that includes transportation (e.g., rail access) and energy-related assets (e.g., power transmission)
- Local and regional economic analysis.

All this information is used to create at least three viable reuse strategy alternatives—"plays"—that would bring new activity to the site and investment and employment benefits to the community.

The goal of DCED's work is to entice transformational redevelopment of legacy industrial properties. By characterizing the site and recommending various paths forward, the playbooks represent the Commonwealth initiative to provide critical information to visionary community leaders and investors to recognize and act upon the opportunities such sites offer.

legislation. The timeframe for implementing this strategy spans decades, and the speed at which the strategy can be implemented influences how fast clean energy sources can be developed. In addition to policy targets, market forces will be critical in determining the mix of resources. The combination of resources used to meet the requirements will be decided on a least-cost basis. Least cost will determine whether emerging technologies such as carbon capture and sequestration are used to meet the requirements—whether they become commercially viable and cost-competitive with other carbon-free grid technologies and fuels, such as solar.

To build a carbon-free grid, strategies are needed to facilitate the siting and development of solar and wind projects, including transmission planning. Collaboration between utilities and local governments will be crucial to develop siting and interconnection standards to ensure that the clean energy targets are met. Neither the Commonwealth nor DEP has jurisdiction on land use for renewable energy projects, however through collaboration, best practices for land use should be encouraged. Solar photovoltaics should be recommended for land uses that have already been impacted such as brownfields, warehouses, and abandoned mines and fields. Soil and land carbon management practices should be encouraged throughout for all photovoltaic projects to maximize carbon reductions.

Potential for low carbon microgrids:

Most residents and businesses received their electricity through their local utilities, which are supplied by large electricity generators and transmission lines. Another option that is becoming increasingly available is microgrids. Microgrids are relatively small, independently controlled power systems that can be operated in concert with, or apart from, the local distribution and transmission system. At the Philadelphia Navy Yard, their microgrid is powered by a variety of sources including an on-site solar project. In a changing electricity grid, microgrids may play an increased role to provide reliable and low-carbon electricity for critical infrastructure such as hospitals, schools, or shelters.

Possible challenges to implementing the strategy include lack of political will in passing grid decarbonization legislation and regulatory and siting delays for the deployment of new clean energy assets. To overcome the latter, new regulations to streamline permitting of the generating facilities may be needed. The state will also need to ensure that equity concerns are addressed during the siting process and that the economic benefits of the increased renewable energy development benefit affected and environmental justice communities.

Additional economic challenges include stranded fossil assets and sector-specific job losses at those facilities. There are potential opportunities for gas infrastructure to be used in a carbon-free future, and the state can work with the industry to study options such as using gas

Alternative electricity generation mixes

The electric grid strategies modeled in this plan provide one potential pathway toward a carbon free grid by 2050, however different market conditions or new enabling technologies have the potential to provide similar outcomes through a different grid mix. Alternatives could include enhanced roles for carbon capture use and sequestration technologies, hydrogen used for power generation, or additional distributed energy resources. The 80x50 model's grid mix presented provides geographic diversity and certain advantages, however other pathways might increase the diversity of generation types, while still providing reliable electricity.

infrastructure for RNG. The legislature can also consider creating retraining programs to help workers in the fossil fuel industry find jobs in the state. Finally, reliability will need to be monitored as the grid shifts to lower-carbon resources. With greater reliance on electricity for transportation, resiliency will become even more critical for state residents. Resource and transmission planning at both the grid and distributed levels will be critical to ensure a reliable and resilient grid to supply energy to an increasingly electrified state.

Agriculture

Emissions from the agricultural sector are primarily produced by enteric fermentation, manure management, agricultural soil management, and fuel combustion from tractors and other machinery. Energy efficiency and alternative farming methods such as no-till farming and integrated farm management can help reduce agricultural emissions.

The Commonwealth has a rich history as a major agricultural producer, and agriculture contributes significantly to Pennsylvania's economy today, producing a market value of $7.76 billion in 2017, and employing over 90,000 people. Based on economic value, key crops and livestock include hay, corn, soybeans, nursery plants and flowers, poultry, dairy products, cattle, and pigs.[64] In 2019, there were approximately 52,700 farms and ranches spread across 7.3 million acres.[65] Lancaster, Bradford, Franklin, York, and Berks counties have the most acres of farmland in Pennsylvania.[66]

The strategies proposed to address agriculture emissions reflect existing technological and policy trends that aim to increase energy efficiency and implement agricultural best practices. Two strategies are modeled:

- Use programs, tools, and incentives to increase energy efficiency for agriculture
- Provide trainings and tools to implement agricultural best practices

Together, the modeling results indicate that these strategies will reduce emissions compared to the BAU in 2025 and 2050 (Figure 30) and in 2050 will reduce emissions in the agriculture sector by 232,562 $MTCO_2e$ (see Table 9).

For each strategy, the environmental, economic, and social benefits are reported along with the costs (or savings) associated with the implementation of the strategy. The environmental benefits and costs (or savings) are expressed in terms of GHG emission reductions and changes

---

[64] USDA. N.d. 2017 Census of Agriculture State Profile: Pennsylvania. https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Pennsylvania/cp99042.pdf.

[65] USDA. 2021. 2020 State Agriculture Overview: Pennsylvania. https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=PENNSYLVANIA.

[66] USDA. N.d. 2017 Census of Agriculture State Profile: Pennsylvania. https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Pennsylvania/cp99042.pdf.

in energy and fuel use. The economic impacts are expressed in terms of changes in job numbers, disposable income, and GSP. The social benefits and costs are expressed in terms of impacts on air quality (e.g., changes in the criteria pollutants like SO_2, NO_x, and $PM_{2.5}$) and associated public health and social impacts such as equity and resilience.

Figure 30. Agriculture GHG emissions with reduction strategies compared to business as usual

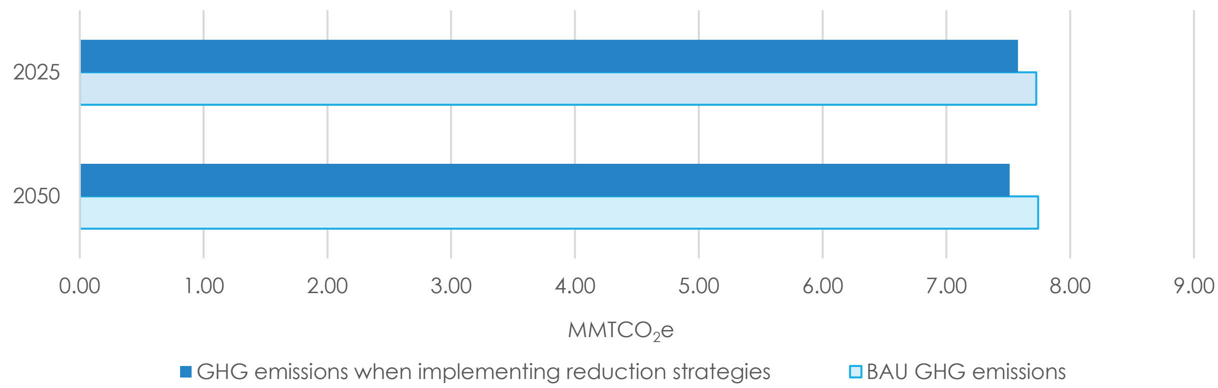


Table 9. Agriculture sector GHG reduction strategies and associated reductions ($MTCO_2e$)

GHG Reduction Strategy	2025	2050
P. Use programs, tools, and incentives to increase energy efficiency for agriculture	2,069	2,965
Q. Provide trainings and tools to implement agricultural best practices	145,799	229,597
Total GHG Reductions	**147,868**	**232,562**

P. 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. For this strategy, energy efficiency improvements are based on a report prepared for DEP by EnSave Inc., titled "Energy Use, Energy Savings, and Energy Efficiency Policy Recommendations for Pennsylvania Agriculture."[67] This report analyzes the potential savings in electricity and fuel consumption that would result from adopting certain efficiency measures.

This strategy estimates potential energy savings for agricultural operations using the commercial energy efficiency savings modeled in the building strategies on energy efficiency (B and C). These savings estimates, based on Act 129, were applied to the technical energy efficiency potential from the EnSave report. The decreases in electricity and fuel consumption were then converted to associated GHG emissions reductions. For this strategy, the measure lifetime was assumed to be 10 years.

Annual GHG emissions reduced in 2025
2,069 $MTCO_2e$

Annual GHG emissions reduced in 2050
2,965 $MTCO_2e$

Annual energy reduced in 2050
14 GWh of electricity
76 BBtu of fuel

Cost or (benefit) per ton of GHG reduced
$43.28/$MTCO_2e$

Net present value
$(3.96 million)

Average annual gross state product
$(0.29 million)

Average annual disposable personal income
$(0.01 million)

Average annual employment
5 jobs

Environmental benefits and costs

By reducing the amount of electricity and fuel consumed through energy efficiency improvements such as equipment and lighting upgrades, this strategy reduces emissions of CO_2 and other GHGs associated with electricity generation and fuel combustion, such as CH_4 and N_2O. This strategy also reduces gaseous and particulate emissions associated with electricity generation and combustion, including criteria pollutants such as NO_x, SO_2, and Hg. Finally, energy savings can be expected from the adoption of more energy efficient measures.

Economic benefits and costs

The macroeconomic impacts of incentivizing energy efficiency for agriculture are small with disparate impacts. Small scale investments are not expected to drive job growth or result in meaningful bill savings, however, they will result in some tightening of budgets and less consumption of other goods and services. Average annual GSP and DPI impacts are expected to

[67] PA DEP. 2020. "Energy Use, Energy Savings, and Energy Efficiency Policy Recommendations for Pennsylvania Agriculture" https://files.dep.state.pa.us/Energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/Pollution%20prevention%20and%20Energy%20assiatance/Energy%20Use,%20Energy%20Savings,%20and%20Energy%20Efficiency%20Policy%20Recommendations%20for%20Pennsylvania%20Agriculture-2020.pdf.

be -$0.29 million and -$0.01 million, respectively. The average annual employment impacts are expected to be 5 jobs.

Social benefits and costs

Improving energy efficiency of on-farm equipment and infrastructure will increase the resilience of a farm's operations. Farmers that have reliable and up-to-date equipment such as refrigeration, ventilation, and lighting systems will be better equipped to handle market changes such as increased fuel prices. Reducing the amount of fuel consumed on farms will also improve the local air quality by reducing the emissions of criteria air pollutants. Lower criteria air pollutant emissions can lead to a better quality of life for farmers and other individuals that live in the area.

Implementation Considerations

Encouraging adoption of energy efficiency measures for agricultural operations will require a coordinated effort between multiple entities including DEP, the federal government, utilities, and institutions of higher education. The involvement of these parties will give farmers a variety of options and programs to choose from, ensuring the most successful outcome. The report prepared by EnSave recommends a series of complementary program offerings for farmers, including promotion of energy audits and incentive funds, a low-interest revolving loan fund, and competitive grants for energy efficiency projects. EnSave also recommends that these programs focus primarily on dairy and poultry operations because they offer the most significant opportunities for energy savings. However, the programs should be offered to all farms regardless of energy savings potential to ensure equitable implementation.

The most significant barriers to implementation of these programs are the relative costs of certain measures and the volatile business environment in which farms operate. For farms where energy costs make up a significant percentage of total operating costs (e.g., poultry), these measures may be a more cost-effective option than on farms where energy costs are not as substantial. Additionally, the precarious financial situation of many farming operations can make the adoption of energy-efficient measures less attractive. However, the potential to reduce energy consumption and improve farmers' bottom lines are valuable opportunities that should be pursued further.

Q. Provide trainings and tools to implement agricultural best practices

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
326 BBtu of fuel

Cost or (benefit) per ton of GHG reduced
$23.84/$MTCO_2e$

Net present value
$(122.66 million)

Average annual gross state product
$(12.01 million)

Average annual disposable personal income
$(12.12 million)

Average annual employment
-219 jobs

This strategy includes trainings and tools to implement agricultural best practices, such as those focused on no-till farming practices and integrated farm management to reduce the amount of GHGs emitted by farmlands. Practices could include rotational grazing, silvopasture, and organic and regenerative agricultural methods. The modeling of this strategy assumes that agricultural practices are implemented with the intention of reducing tillage intensity and thereby lowering GHG emissions.

The modeling for this strategy follows a similar methodology to the 2018 CAP. Tillage practices by crop are based on a survey of Pennsylvania farmers conducted by USDA for 2013 and 2014.[68] The modeling team assumed that the proportion of fields with no-till acreage will increase at a constant rate of 5.9% annually until it reaches 98% of all acres, the maximum potential of no-till adoption. GHG reductions are calculated for both the annual increases in carbon sequestration and the decreases in fuel consumption required for tilling.

Environmental benefits and costs

By reducing the intensity of tillage on agricultural lands, GHG reductions will result from both decreased fuel consumption and increased carbon sequestration on croplands. Reducing tillage intensity decreases the amount of fuel consumed while tilling fields, leading to energy savings and lower GHG emissions (CO_2, CH_4, and N_2O) from the fuel consumption itself. Reduced-till and no-till fields also provide a net environmental benefit by sequestering additional carbon directly from the air. This strategy also reduces gaseous and particulate emissions associated with fuel combustion, including criteria pollutants such as NO_x and SO_2. Note that these emissions reduction benefits are in addition to water quality benefits from no-till such as reduced nitrogen and sediment loads to waterways.

Economic benefits and costs

The implementation of agricultural best practices is expected to have some negative economic impacts. While there are some expected positive impacts of bill savings resulting from decreased fuel consumption, there are also cost associated with machinery related to no-till or air seeding practices. On the net, the economic impacts are expected to be negative. Average

[68] USDA. 2015. "Tillage Practices with Updated Alfalfa Seedings and Final Acreages." Available at: https://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Survey_Results/tillage%202014%20jan%2020125.pdf.

annual GSP and DPI are expected to be -$12.01 million and -$12.12 million, respectively. The average annual employment impacts are expected to be -219 jobs.

Social benefits and costs

Reducing the number of acres tilled annually will lower the amount of fuel consumed to operate tillage machinery. Reduced fuel consumption on farms will improve the local air quality by reducing the emissions of criteria air pollutants. Lower criteria air pollutant emissions can lead to a better quality of life for farmers and others who live in the area.

Implementation Considerations

Reducing tillage intensity is an important practice that can benefit the broader environment by increasing carbon sequestration as well as the local environment by reducing runoff and soil erosion. No-till operations, which typically involve the use of a cover crop, are becoming a common practice for farmers who want to maintain soil health and improve their crop's productivity. Implementation of no-till and other soil management practices can be facilitated through education and outreach from DEP and other state actors. Coordination with the Penn State Extension System, farmers' co-ops, and other educational or community programs will be necessary to educate farmers about the environmental benefits (e.g., GHG reductions, improved soil health) of reducing tillage beyond cost savings and decreased fuel consumption.

The technology required to adopt no-till practices already exists, so the most important step is conducting outreach to farmers and helping them apply these technologies to their farms. While convincing farmers to change their behavior or adopt new techniques can be a challenge, the benefits of improving soil health and reducing runoff provide significant incentives to act. Reducing tillage intensity is a promising area of interest for the agriculture sector in Pennsylvania. The opportunities to improve soil health and increase carbon sequestration make it an attractive option for DEP and other ag interest groups to promote statewide.

Resilience Considerations

Implementation of best management practices (BMPs) in agriculture such as reduced tillage may also reduce flood risk (e.g., by allowing soils to hold more water), thereby increasing farms' resilience to projected increased flood risks under climate change.[69] BMPs may also improve the sustainability of agricultural practices to cope under changing climate conditions, reduce erosion, and improve soil health.

In addition, Pennsylvania has the opportunity through this strategy to simultaneously provide training and tools that can help farmers adapt to climate change impacts (see Section 4 on Addressing the Impacts of a Warmer and Wetter Climate on Agriculture).

---

[69] Antolini, F., Tate, E., Dalzell, B., Young, N., Johnson, K., and Hawthorne, P.L. 2020. " Flood Risk Reduction from Agricultural Best Management Practices." Journal of the American Water Resources Association 56 (1): 161– 179. https://doi.org/10.1111/1752-1688.12812; White, P.A. 2015. "Can Soil Save Us? Making the Case for Cover Crops as Extreme Weather Risk Management." National Wildlife Federation (NWF). Available at: https://www.nwf.org/~/media/PDFs/Water/2015/Drought-and-Flood-Report-Final.pdf

Land Use, Land-Use Change, and Forestry

The land use, land use change, and forestry (LULUCF) sector includes all land that is not developed for agricultural, industrial, or residential uses, and activities on those lands that either capture (i.e., sequester) CO_2 or release GHG emissions. 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. Strategies to increase the sequestration of CO_2 by using these sinks include reforestation and afforestation, enhanced soil carbon uptake, and biochar.

Pennsylvania enjoys diverse and widespread forests that cover 16.9 million acres of land, or about 58% of all land in the Commonwealth.[70] Common tree species include oak, maple, hickory, birch, and beech, which provide many economic and environmental benefits such as lumber, food, wildlife habitat, and clean air and water. Forests also offer a range of recreation activities such as camping, hiking, fishing, and hunting.

Other land types that are less prevalent than forests but equally important are wetlands and coastal areas, such as along the Delaware Bay and the shore of Lake Erie. Wetlands are typically found near floodplains along rivers and streams, in swamps or marshes, and around lakes. Wetlands are vital breeding and spawning grounds for many animals, including amphibians, birds, and fish. Some of Pennsylvania's threatened and endangered species, like the American bittern, are only found in wetlands.

The strategy proposed to address LULUCF emissions reflects technology and policies that aim to sequester more GHG emissions by increasing forest cover. One strategy is modeled: land and forest management for natural sequestration and increased urban green space. The modeling results indicate that this strategy will reduce emissions compared to the BAU in 2025 and 2050 (Figure 31), and in 2050 will reduce emissions in the LULUCF sector by 2,930,193 $MTCO_2e$ by 2050 (see Table 10).

For each strategy, the environmental, economic, and social benefits are reported along with the costs (or savings) associated with the implementation of the strategy. The environmental benefits and costs (or savings) are expressed in terms of GHG emission reductions and changes in energy and fuel use. The economic impacts are expressed in terms of changes in job numbers, disposable income, and GSP. The social benefits and costs are expressed in terms of impacts on air quality (e.g., changes in the criteria pollutants like SO_2, NO_x and $PM_{2.5}$) and associated public health and social impacts such as equity and resilience.

[70] USDA. 2016. "Forests of Pennsylvania, 2015. https://www.fs.fed.us/nrs/pubs/ru/ru_fs92.pdf.

Figure 31. LULUCF GHG emissions with reduction strategies compared to business as usual

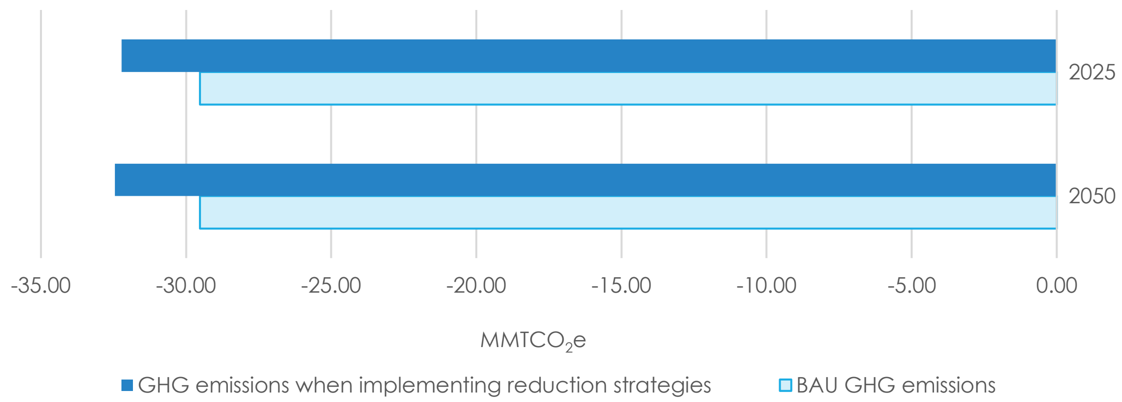


Table 10. LULUCF sector GHG reduction strategies and associated reductions ($MTCO_2e$)

GHG Reduction Strategy	2025	2050
R. Increase land and forest management for natural sequestration	2,698,407	2,930,193
Total GHG Reductions	**2,698,407**	**2,930,193**

R. Increase land and forest management for natural sequestration

Annual GHG emissions reduced in 2025
2,698,407 $MTCO_2e$

Annual GHG emissions reduced in 2050
2,930,193 $MTCO_2e$

Pennsylvania's 6.9 million hectares (17 million acres) of forest land are estimated to sequester about 34 million $MTCO_2e$ annually. Of several natural strategies evaluated for their potential to increase the carbon sequestration of forestland in Pennsylvania, extending harvest cycles and reforestation showed the highest potential.[71,72,73] Afforestation of abandoned/legacy mine lands and marginalized croplands (cropland uncultivated due to challenging soil conditions) offer additional opportunities through expansion on land with no competing uses.

The potential for increased carbon sequestration was evaluated for a series of land management strategies, including:

- **Reforestation** of forest and urban open spaces, suitable shrub and grass areas, pasture, and marginal crop land
- **Afforestation** (establishment of new forest) on abandoned mine lands

[71] Cook-Patton, S. C., Gopalakrishna, T., Daigneault, A., Leavitt, S. M., Platt, J., Scull, S. M., Fargione, J. E. (2020). Lower cost and more feasible options to restore forest cover in the contiguous United States for climate mitigation. One Earth, 3(6), 739-752. doi:10.1016/j.oneear.2020.11.013.

[72] Fargione, J. E., Bassett, S., Boucher, T., Bridgham, S. D., Conant, R. T., Cook-Patton, S. C., Griscom, B. W. (2018). Natural climate solutions for the United States. Science Advances, 4(11). doi:10.1126/sciadv.aat1869.

[73] Dugan, A., Steele, A., Hollinger, D., Birdsey, R., & Lichstein, J. (2018). Assessment of Forest Sector Carbon Stocks and Mitigation Potential for the State Forests of Pennsylvania. doi:10.32747/2018.6893743.ch.

- **Extend harvest cycles**, where feasible (on state, private, and other lands) coupled with a 5% increase in long-lived wood products.

The total area of opportunity for strategies based on expanding forest area was estimated for 906,652 hectares, assuming that a combination of land types would be utilized including abandoned mine lands, marginal croplands, pasture, and urban open spaces.[71] A five-year implementation period was assumed for these strategies except for pasturelands, which were projected to be reforested at a rate of 5% per year (based on the total area of opportunity). Estimates used oak-hickory due to their dominance in the state's forests, high-value to the timber industry, and superior food provision for wildlife.

Pennsylvania's forestlands may reduce atmospheric CO_2 levels either directly (through reforestation/afforestation that increases CO_2 uptake) or indirectly through the increased use of wood products from Pennsylvania's forests in place of other materials in buildings and consumer products. Materials substitution as a strategy would maintain forest management jobs while creating additional opportunities in processing and manufacturing.

There are many variables in forest management including historic practices, forest age and type, and quality and type of soils. Considering these variables, the most effective practice for sequestering carbon and reducing emissions is to keep forests as forests, and encourage healthy, diverse forests representing a variety of age classes across the state. State forests should maintain extended harvest rotations in suitable areas such as steep slopes, riparian buffers, and wild and natural areas, where tree age can extend to 130 years and beyond. Harvest rotations on private and other forest ownership types should be extended, where practicable based on forest type and location. It is important for forests to be well-managed for pests, disease and intentionally managing for carbon as well as other values.

Environmental benefits and costs

This strategy will result in GHG reductions from the additional carbon sequestered by new forest land. Abandoned mine lands and marginalized croplands have little to no carbon sequestration potential, so any new forest land that replaces these land types will lead to net reductions in GHG emissions. Increased biodiversity, improved water quality, erosion prevention, and reduced urban heat effect are some additional environmental co-benefits that can be expected from improved forests. Most of the sequestration potential occurs beyond 2025 due to the time required for implementation, i.e., for trees to grow. Promoting practices that diversify and enhance long-term forest health and therefore increase carbon sequestration and storage are key practices that currently yield environmental benefits.

Economic benefits and costs

Sustainable timber supply, diversification of farm income from added hardwood, and improved livestock performance are some expected economic development benefits that this strategy can provide. Expanding forestlands involves establishment costs if active planting is used, and also involves opportunity costs in foregone revenues from cropland, pastureland, or delaying timber harvests. Natural regeneration and extending harvest cycles involve minimal establishment costs. Estimated annualized planting costs with active planting are $171/hectare-year.[71] Including opportunity costs from these lands would require a carbon price of $40/ton$CO_2$e to incentivize landowners to engage in forestland expansion. Abandoned mine lands require extensive site preparation costing $6,175/hectare to $8,645/hectare depending on tree type and spacing. Legacy mine lands will incur additional costs due to required site preparation such as deep tilling of heavily compacted soil and control of existing vegetation. Compacted topsoil on legacy mine lands often requires deep tillage and removal of any invasive vegetation before a productive forest can be established.[74]

Indirect pathways for utilizing forest products to reduce atmospheric CO_2 concentrations through substituting wood for materials like cement and steel have received less direct attention in terms of costs, benefits, and relative GHG concentration reductions. Lippke, et al. (2010)[75] and Oliver et al. (2014)[76] estimate that the use of wood as a building material could reduce the GHG footprint of a building by almost 50% compared to concrete and steel, but this analysis is limited to materials substitution and does not consider forest management strategies. The performance of a strategy focused on forest product substitution in buildings and consumer product manufacturing versus extension of harvest cycles has been raised as an important policy consideration in forest management[77,78] but has not been extensively studied and represents a gap relevant to Pennsylvania forest management decisions.

Social benefits and costs

Increasing the amount of forest land will help to improve air and water quality, as forests act as a natural filter for pollutants in the air and water sources. Increased tree cover can also mitigate the effects of urban heat islands, reducing the level of heat stress placed on individuals that live near forests. Forests are an important public resource that provide a source of recreation and enjoyment. Marginal croplands or abandoned mine lands that are converted into forests could be repurposed into public parks and recreational areas.

Resilience Considerations

Depending on where reforestation, afforestation and harvest cycle extension practices occur, there may be an opportunity for them to provide additional resilience benefits, such as reducing urban heat island effects, or improving ecosystem connectivity or reducing runoff or flood risks (see Section 4 on Addressing the Impacts of Increasing Average Temperatures on Forests, Ecosystems, and Wildlife).

---

[74] Jacobson, M. (2021). Personal communication between Michael Jacobson and Pennsylvania State University.

[75] Lippke, B., Wilson, J., Meil, J., & Taylor, A. (2010). Characterizing the importance of carbon stored in wood products. Wood and Fiber Science, 42, 5-14.

[76] Oliver, C. D., Nassar, N. T., Lippke, B. R., & McCarter, J. B. (2014). Carbon, fossil fuel, and biodiversity mitigation with wood and forests. Journal of Sustainable Forestry, 33(3), 248-275.

[77] Malmsheimer, Robert W., et al. "Managing forests because carbon matters: integrating energy, products, and land management policy." *Journal of Forestry. 109 (7S): S7-S50* 109.7S (2011): S7-S50.

[78] Miner, Reid A., et al. "Forest carbon accounting considerations in US bioenergy policy." *Journal of Forestry* 112.6 (2014): 591-606.

Implementation Considerations

Necessary actions to implement the strategies will include identifying areas needing active or limited management versus where natural regeneration can occur. Additional considerations will include identification of funding sources and appropriate incentives (for private owners), creating public awareness, identification of sufficient planting stock, and establishment of monitoring and maintenance regimes.[71] Private and public land managers will need to be equipped with the appropriate tools, information, and the flexibility to incorporate climate change in management planning and implementation.

Private land ownership greatly influences management and implementation actions. The PA DCNR is mandated with managing the state's forest land. It also provides information and technical advice to private forest landowners and establishes community conservation partnerships. Federal land managers include the National Park Service, U.S. Forest Service, and Fish and Wildlife Service, which oversee 80%, 10% and 10% of federally owned land, respectively. Multi-state partnerships work in collaboration with federal agencies to provide technical guidance. The Appalachian Regional Reforestation Initiative, for example, guides the restoration of high-quality hardwood forests on reclaimed coal mines.

Given the linkages of ecological, economic, and social systems, to ensure that local and non-local needs are met, management decisions and policies should be guided by expert science as well as local and indigenous knowledge through community participation.

Waste

The waste sector includes all activities related to the collection, transportation, processing, and disposal of waste. Unwanted or discarded materials are considered waste. Categories of waste sources include industrial, municipal, residual, and hazardous waste. The following are the primary sources of GHG emissions from the waste sector:

- Landfills (primarily in the form of landfill gas, a natural byproduct of decomposed organic materials)
- Waste-to-energy facilities (primarily from the combustion of solid waste)
- Wastewater treatment plants (from the digestion of biosolids)

Waste transportation and related activities produce additional emissions. Currently in Pennsylvania, there are 43 municipal waste landfills, four construction and demolition waste landfills, and six waste-to-energy facilities.[79] The municipal waste industry in Pennsylvania collected, hauled, and disposed of 8.7 million tons of municipal solid waste in 2016, or about

[79] DEP. 2021. "Municipal Waste Landfills and Resource Recovery Facilities." Available at: https://www.dep.pa.gov/Business/Land/Waste/SolidWaste/MunicipalWaste/MunicipalWastePermitting/Pages/MW-Landfills-and-Resource-Recovery-Facilities.aspx.

1,360 pounds per person. The most common landfilled materials were food waste, non-recyclable paper, corrugated cardboard, newspaper, and mixed paper.[80]

Recycling and reusing materials are methods to reduce the amount of waste generated. In 2017, more than 6.36 million tons of materials were collected and recycled, mitigating approximately 8.78 $MMTCO_2$.[81] Unfortunately, recycling rates are falling across the Commonwealth and country due to the elimination of a significant portion of worldwide recycling processing capacity. Many local governments in Pennsylvania are scaling back or eliminating their recycling programs due to the increased cost and the shrinking market for recyclable materials.[82]

While the waste sector is an important emissions source and there are strategies to reduce waste sector emissions, these strategies were not modeled for the CAP.

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 storage (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

---

[80] PWIA. 2021. "Waste Facts." Available at: http://pawasteindustries.org/waste-industry/waste-facts/#:~:text=As%20of%202016%2C%20Pennsylvanians%20generate,pounds%20per%20person%20every%20year!.

[81] DEP. 2021. "Statewide Recycling Data." Available at: https://www.dep.pa.gov/Business/Land/Waste/Recycling/Pages/Recycling-Reports-and-Studies.aspx.

[82] Waste Dive. 2019. "How Recycling Has Changed in all 50 States." Available at: https://www.wastedive.com/news/what-chinese-import-policies-mean-for-all-50-states/510751/.

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 can potentially serve as an alternative to new or upgraded transmission lines.

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 other 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.[83] See Figure 32 for recent battery price information.[84] Lithium-ion technologies are the leading energy storage solution; however, several other technologies are under investigation for grid-scale applications including vehicle-to-grid technologies, lead-acid, redox flow, and molten salt.[85] 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. Battery technology may also be relevant for Electric Distribution Companies (EDC), who may play a role in battery ownership in the distribution grid. The PUC has issued a letter soliciting comments regarding EDC battery ownership as they look to inform future regulatory policies related to battery technologies.[86]

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.[87] 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.

---

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

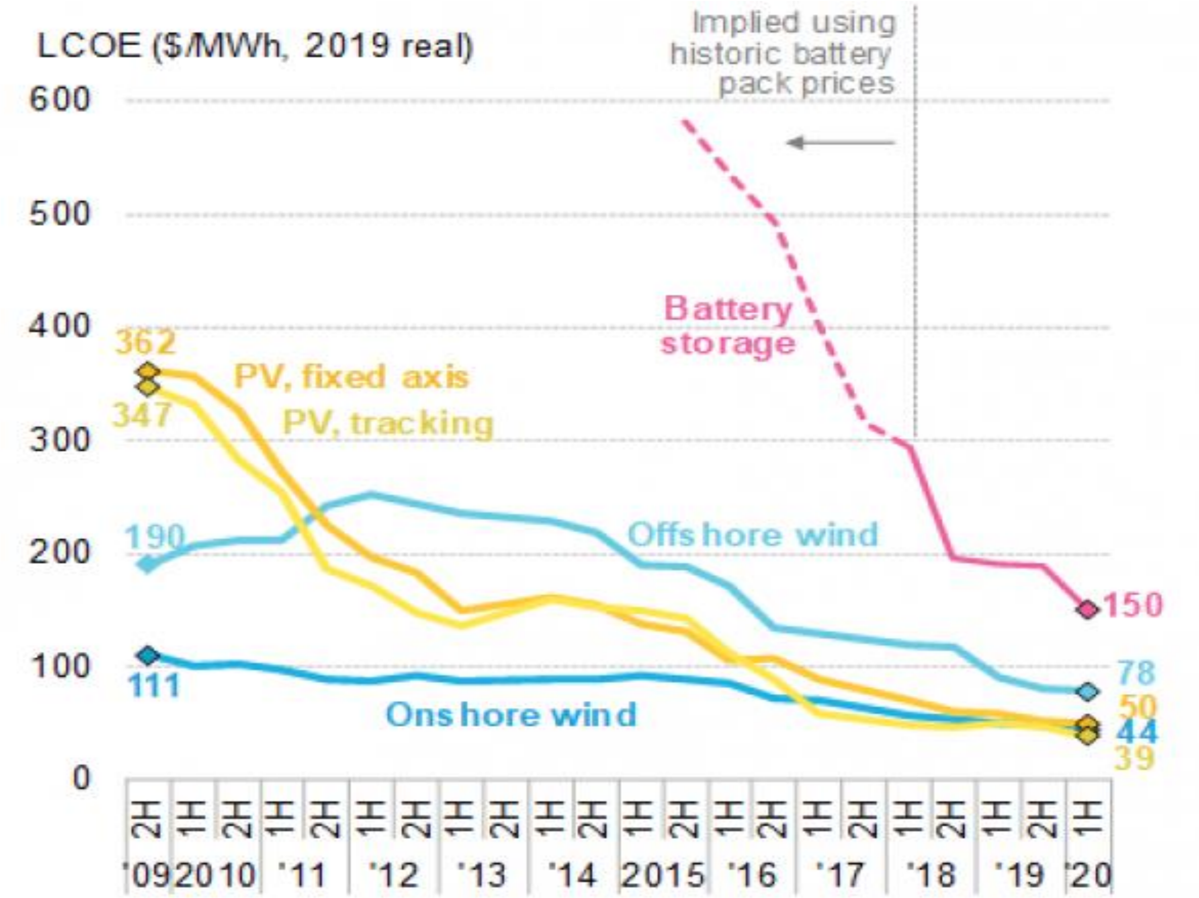
[84] Energy Storage News. 2020. "BloombergNEF: 'Already cheaper to install new-build battery storage than peaking plants.'" Accessed December 15, 2020. Available at: https://www.energy-storage.news/news/bloombergnef-lcoe-of-battery-storage-has-fallen-faster-than-solar-or-wind-i.

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

[86] Pennsylvania Public Utility Commission. 2020. "Policy Proceeding—Utilization of Storage Resources as Electric Distribution Assets". Accessed March 15, 2020. Available at: http://www.puc.pa.gov/pcdocs/1686327.doc.

[87] 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.

Figure 32. Global levelized cost of energy of battery storage technology relative to renewable energy generation technologies



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.

The Path Forward for Increasing Energy Storage Statewide

Current context

- There are about 1.5 gigawatts (GW) of energy storage capacity in Pennsylvania. This represents 22 operational or announced energy-storage projects, including pumped hydro storage (1.07 GW), lithium-ion batteries (18 megawatts [MW]), lead carbon batteries (12.5 MW), ice and chilled water thermal storage (6 MW), and other technologies providing smaller amounts.
- As of February 2021, there were 64 solar-plus-storage projects, reaching 2.3 GW, in the Pennsylvania portion of the planning queue of PJM, the wholesale electric regional transmission organization serving 14 states. Although these projects are still in early stages and not yet announced, the trend reflects growing recognition of the value of solar-plus-storage.
- Workers and companies are developing energy storage equipment in Pennsylvania today. For example, Arkema, in King of Prussia, was awarded $5 million from the U.S. Department of Energy to develop lithium-ion energy storage manufacturing processes. East Penn Manufacturing, in Lyon Station, recycles 30,000 batteries a day. Eos Energy Storage, in partnership with Holtec International, is producing aqueous zinc batteries for industrial-scale energy storage in Pittsburgh.
- Several entities are doing research and development, including Penn State University Battery and Energy Storage Technology Center and the University of Pittsburgh Energy GRID Institute.

Moving ahead

The 2021 report *Pennsylvania Energy Storage Assessment: Status, Barriers, and Opportunities* recommends:

- Pairing grid-scale solar arrays with battery storage to reduce carbon emissions and increase grid resilience, and catalyzing the action by setting an energy storage capacity target, as seven other states have done.
- The Energy Storage Assessment recommends 14 other measures to foster energy storage investment and integration, including convening a statewide storage issues forum, designating public funding to accelerate storage deployment, establishing incentive programs for storage projects, and accelerating microgrid deployment at critical facilities.
- The assessment report recommends supporting research and development by institutions and businesses in state to innovate energy storage technologies that can incorporate common elements and environmentally friendly design and be made in Pennsylvania.

Source: DEP and Strategen Consulting. 2021. Pennsylvania Energy Storage Assessment: Status, Barriers, and Opportunities. https://files.dep.state.pa.us/Energy/Office of Energy and Technology/OETDPortalFiles/EnergyAssurance/Strategen_PA_Energy_Storage_Assessment_April_2021.pdf.

Analyze the potential role of power-to-gas and blue and green hydrogen 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 including in transport, buildings, and electricity generation. 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 as a fuel is not found in nature, but can be derived through various processes, some of which can reduce GHG emissions. Once created, hydrogen can be stored, transferred to other locations by truck or pipeline, or used for various purposes. The demand for hydrogen has tripled since 1975, and production costs have decreased as research advances. The International Energy Agency (IEA) recommends investing in and scaling up hydrogen production as the costs continue to decline and the world seeks to reduce CO_2 emissions.[88] Hydrogen, when used in a fuel cell, emits zero emissions, and when combusted, results in NO_x emissions. Hydrogen can be produced from a variety of resources, including natural gas and biomass or via electrolysis using electricity (i.e., P2G).

Hydrogen Terminology

Power-to-gas is a process that uses electrical power and electrolysis to split water into oxygen and hydrogen so the hydrogen can be used as a gaseous fuel. Power-to-gas may also refer to synthetic gas which is derived from hydrogen using subsequent processes.

Blue Hydrogen is derived from fossil sources such as natural gas but uses carbon capture and sequestration technology to reduce the CO_2 emissions produced to create hydrogen.

Green Hydrogen is hydrogen created from renewable energy sources such as solar, wind, hydropower, 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 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. Hydrogen can provide a future carbon-free option that would potentially reduce the risk of stranded assets (e.g., energy distribution systems).

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 (e.g., steel refining or food production), or as fuels for heavy-duty or off-road vehicles.

[88] International Energy Association (IEA). 2019. *The Future of Hydrogen*. Available at: https://www.iea.org/reports/the-future-of-hydrogen.

Hydrogen may require new or retrofitted equipment so that it can be used as a fuel. Equipment, infrastructure, and vehicle incremental costs will need to be understood by users as they will differ significantly from existing fuels and may require significant investments. Hydrogen may serve as a lower cost fuel option for low-emission vehicles for large fleets of heavy-duty vehicles as the infrastructure and vehicle costs together are considerably lower when compared to heavy duty electric 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 emissions from the electrical, industrial, and other sectors 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.[89] 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, used to enhance petroleum hydrocarbon production, or repurposed in industrial and manufacturing processes.

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. Federal incentives such as the 45Q tax credit are making CCUS technologies more financially feasible, spurring commercial growth in the sector. While CCUS can help capture CO_2 emissions at source points, it is not a substitute for strategies that prevent or reduce emissions. CCUS can play a significant role in reducing CO_2 emissions from multiple sectors and must be part of a larger multi-disciplinary strategy to achieve carbon neutrality. Land-based sequestration strategies must be considered in concert with geologic storage opportunities to manage competing uses of Pennsylvania's natural and geologic resources.

Why it matters for Pennsylvania: The Commonwealth has a potential geologic sequestration capacity of 88.5 gigatons, enough to store hundreds of years of CO_2 emissions, primarily due to the deep saline formations underground.[90] Additionally, as a major oil and gas producer, it has notable potential to use CCUS technologies for enhanced recovery of petroleum hydrocarbons, 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 (see text box for

---

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

[90] 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/.

details).[91] Together, these factors indicate that the Commonwealth is well positioned to implement CCUS technologies and policies that not only offer significant climate benefits but also bolster the economy by supporting existing and new innovative industries in a carbon-constrained world. Furthermore, by implementing CCUS technologies, Pennsylvania's electricity generators, fossil fuel producers and processors, and high-emitting industries will be poised not only to survive the transition to a decarbonized future but also thrive in a zero-carbon economy. 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. Realizing that CCUS is both an environmental imperative and an economic opportunity, the Commonwealth launched a CCUS Inter-Agency Work Group in 2019 to identify collaborative opportunities to expedite CCUS in Pennsylvania.[92]

Multistate Initiative to Develop CO_2 Transport Infrastructure

Pennsylvania, Kansas, Louisiana, Maryland, Montana, Oklahoma, and Wyoming signed a memorandum of understanding in 2020 to commit to establishing and implementing a CO_2 transport infrastructure in an effort to ensure energy security, create and preserve jobs, and reduce net carbon emissions. The initiative plans to release its action plan in October 2021 and will identify barriers to regional CCUS and recommendations to overcome them.

Pennsylvania's opportunities for climate change mitigation are best served by providing a comprehensive approach to natural resource management that considers competing land uses and coordinates access to terrestrial and geologic resources.

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–

---

[91] Pennsylvania Department of Community and Economic Development (DCED). 2020. "Pennsylvania Joins 6 States in Commitment to Plan for CO_2 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/.

[92] 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.[93] DAC is considered to be among the most expensive carbon capture technologies—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. This is due to several factors, but primarily to high energy demand and high production and operating costs. (A few pilot projects claim to achieve commercial scale, though there is not a clear definition of what constitutes commercial scale for DAC.[94]) However, in the past 10 years, several businesses and research institutions have made significant advances to reduce the costs and improve the efficiency of DAC technologies. DAC has gained attention as a tool against climate change as it is becoming clear that meeting midcentury emissions and global warming goals will probably require the world 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 in the coming decades, DAC is likely to play a larger role. Providing resources and education to energy providers and regulators, businesses, academic and research institutions, and other stakeholders now may enable the adoption of better 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. When commercially viable, 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 strategy for CCUS and infrastructure, notably the recent multistate CO_2 transportation project. DAC requires significant energy inputs, though this may not prevent a major energy producer like 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 very versatile, but to keep the grid in balance, electricity must be used at the same time and in the same quantity as it is generated. Flexible grids and load management techniques such as demand-and-response and peak load management programs help solve this challenge as they are capable of reducing electricity demand, which helps to keep the grid in balance and reduces large load peaks. Large load peaks, if not abated, can result in increased costs and potential grid disruptions. 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 contributes to variability. Distributed energy resources (DER) and small-scale battery storage projects may also play a role in balancing the grid by generating

---

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

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

power at times of peak demand. The Federal Energy Regulatory Commission (FERC) recently allowed distributed energy resources to participate in wholesale markets as aggregated sources and contribute to load management and grid balancing.[95]

Presently, grid interruptions occur when sudden power plant shutdowns, transmission line outages, or distribution system failures occur; however, larger grid reliability issues may occur in the future. Load management and other load flexibility technologies and programs can help mitigate these challenges. For example, wider application of time-of-use rates provides economic incentives for customers to use electricity in ways that reduce peak loads. Dual fuel heat pumps use natural gas to support electric heat pumps and reduce electricity peaks that could occur in winter months. Direct load control, typically applied to HVAC and hot water systems, is an established load management approach. Battery storage is emerging as a peak load management and grid reliability technology, deployed at grid scale, at the building level, or in electric vehicle-to-grid integration schemes.[96]

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 the costs of operating the grid and can provide revenue to participants. As Pennsylvania's electricity grid changes and variable sources such as wind and solar are incorporated, load management of grid peaks will be needed for 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 or low-income residents.

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

Carbon offsets include 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 or costly to reduce under the policy scheme. Offsets are typically included in a policy framework as certificates that represents a one $MTCO_2$ or equivalent reduction. Offsets are most commonly administered 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 in addition to any reduction in emissions that would have been achieved through regulatory compliance. An offset project must pass strict verification to be certified as genuine.[97] 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

[95] FERC Order 2222 enables DER aggregators to compete in regional organized wholesale electric markets, but the rules for implementation are still under consideration by states, grid operators, and FERC.

[96] 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.

[97] Stockholm Environment Institute and Greenhouse Gas Management Institute (SEI and GHGMI). N.d. Available at: https://www.offsetguide.org/understanding-carbon-offsets/.

governmental bodies) and voluntary carbon offsetting (typically run by nongovernmental organizations).

Offsets are provided by a program or an entity that takes some action—planting trees, installing renewable energy infrastructure, or a similar action—that will mitigate or sequester CO_2 (or other GHG) emissions. An organization may pursue carbon offsets when the cost of the offset is lower than directly reducing its own carbon footprint. Individuals can also purchase offsets. For example, many people purchase carbon offsets for the emissions that result from their airplane travel. Offset prices range from less than $1 per $MTCO_2e$ to more than $50 per $MTCO_2e$, though prices vary by project type and offset program, and few offsets exceed $15 per $MTCO_2e$.[98] Carbon offsets must meet the following requirements:

- Be verified as legitimate (i.e., a trusted third-party verifies that the offset action will truly reduce emissions)
- Be "additional" (i.e., the activity would not have taken place without the purchase of the offset)
- Be real and permanent (i.e., an acre of trees was actually planted and will not be cut down right after the offset is issued)[99]

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 carbon offset markets 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 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" and high-speed networks such as 5G (fifth-generation cellular technology standards), are disrupting traditional business models and standard industry processes. The internet of things allows everyday devices to connect to the internet and transmit data (e.g., smart thermostats); widespread application of the internet of things relies on a high-speed 5G network to exchange data, implement updates, and track performance, and 5G is being rolled out nationwide. Artificial intelligence and advanced algorithms are increasingly built into digital technologies, a trend that is expected to continue to grow in the coming years. The potential costs, barriers to implementation, and impacts of

[98] Forest Trends. 2017. Unlocking Potential: State of the Voluntary Carbon Markets 2017. Available at: https://www.forest-trends.org/wp-content/uploads/2017/07/doc_5591.pdf.

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

digital technologies vary greatly based on the scale and scope of application, yet they will undoubtedly reshape the energy sector in the next 10 years.

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. 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 education and changes in regulations or rules that affect market conditions and that can also stimulate the installation or economic viability of certain technologies. These technologies have applications in all sectors.

Why it matters for Pennsylvania: Disruptive digital technologies have the potential to strengthen Pennsylvania's energy sector by improving efficiency and optimization. Integrating 5G and the internet of things 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 with increased connectivity, and the Commonwealth must improve its capability to respond and adapt to the changing demand.

4 OPPORTUNITIES TO ADAPT TO THE IMPACTS OF CLIMATE CHANGE

Overview of Impacts of Climate Change Already Happening in Pennsylvania

As a result of projected climate changes, the Commonwealth will be impacted in a variety of ways. The 2021 Impacts Assessment analyzed how the six climate change hazards studied might affect different sectors in Pennsylvania. Key findings from the assessment are described below.

Risks from Specific Hazards

In the 2021 Pennsylvania Climate Impacts Assessment, **Impacts** refer to the effects of a climate hazard (e.g., potential impacts of warmer temperatures include health risks on hot days). In the Impacts Assessment, the likelihood and consequences (i.e., severity of impacts) of hazards were weighed together to assess relative risks of climate hazards on each sector and to identify priority areas of focus for adaptation.

Flooding is currently the highest risk hazard, and flood risks are projected to increase. Flooding from heavy rain events affects built infrastructure, human health, and agriculture and has ripple effects throughout the economy.

Increasing average temperatures and heat waves create risks that could reach risk levels as high as flooding is today by midcentury.

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 people, 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

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 Impacts Assessment, seven priority areas were identified for climate adaptation:

- Increasing heat and flooding on health
- Increasing heat and flooding on overburdened and vulnerable populations
- Increasing average temperatures on forests, ecosystems, and wildlife
- Warmer and wetter climate on agriculture
- Increasing average temperatures on recreation and tourism
- Flooding on built infrastructure
- Landslides on built infrastructure

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.

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 Impacts 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
- Support the agriculture, recreation, and tourism sectors, as well as forests, ecosystems, and wildlife in the transition to a warmer climate

The remainder of this chapter describes opportunities for the Commonwealth to adapt to those impacts—that is, to take action to prepare for, reduce, or avoid negative impacts and capitalize on potential opportunities created by climate change, and in a way that equitably serves all Pennsylvanians.

These adaptation opportunities are complementary to ongoing hazard mitigation activities, with a particular emphasis on how the Commonwealth can mitigate risks associated with changes in climate (and associated changes in hazard likelihood or severity).

Adaptation Pathways

For each priority adaptation area, the CAP outlines an adaptation strategy pathway to manage the risk over time. Adaptation pathways outline the steps, options, and decision points involved over time. Each pathway includes:

Adaptive management is an iterative risk management approach. As conditions change, adaptive management suggests using adaptation actions that address current risks and preparing for variable future changes. This approach provides flexibility to assess continuously changing risks and undertake appropriate actions to mitigate those risks.

The adaptation strategy pathways developed in the CAP are intended to provide ways the Commonwealth can adaptively manage impacts over time.

Adapted from Lempert, R., J. Arnold, R. Pulwarty, K. Gordon, K. Greig, C. Hawkins Hoffman, D. Sands, and C. Werrell. 2018. "Reducing Risks Through Adaptation Actions." In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 1309–1345. doi: 10.7930/NCA4.2018.CH28

- **Foundational strategies** that serve as mechanisms for the Commonwealth to improve its understanding of impacts. These strategies typically involve identifying and prioritizing impacts through mapping, data collection, research, community engagement, and monitoring. Gaining a clear picture of impacts early on enables adaptive management (see box at right) moving forward.
- **Strategy categories** that generalize approaches for tackling impacts in each priority area; for example, funding support, technical assistance, construction projects, and education and outreach. Specific strategies fall within these approach categories. These approaches aim to reduce existing challenges and stressors related to climate impacts and to minimize future challenges.
- **Example strategies** for each strategy category provide illustrations of actions that can be taken or mechanisms that can be implemented for a given approach. Appendix C highlights resources to explore more adaptation strategies.

Pathways also specify:

- **Key actors** in Pennsylvania who could engage in adaptation efforts in the priority area.
- **An example progression** of four strategies that illustrates a potential route for adaptation in the priority area. These sets of strategies note the timing of strategies, the relevant actors, the foundational strategies, and the applicable strategy category.
- **An overview of costs and benefits** of adaptation. The qualitative discussion frames the level of resources needed to pursue adaptation efforts and the co-benefits of adaptation.
- **A case study** that exemplifies adaptation in the priority area. The case study dives into the adaptation strategies being pursued and highlights the outcomes of the efforts.

To develop each adaptation pathway, the analysis team first compiled adaptation strategies for each priority adaptation area, based on:

- 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 throughout the country

The analysis team then reviewed and refined the compilation of strategies to align with the most significant impacts identified in each priority area in the 2021 Impacts Assessment. The analysis team then categorized the strategies into types of approaches for stakeholders to consider.

The analysis team summarized strategy categories by considering their character and timing. Foundational strategies are characterized as actions that document and improve the understanding of impacts. Strategy categories include strategies focused on direct adaptation efforts or indirect actions that would enable adaptation. With this framework, the analysis team developed each adaptation strategy pathway.

These pathways are intentionally broad and flexible. Each pathway provides possible directions for pursuing adaptation over time. Actions may be adopted as resources and/or more information becomes available. The pathways serve as an illustrative guide for the Commonwealth to reduce pressing impacts and to seize on the opportunities available in each priority area.

The sections below outline pathways for Pennsylvania to adapt to the impacts of climate change in the priority areas designated in the Impacts Assessment.

- Addressing the impacts of increasing heat and flooding on health
- Addressing the impacts of increasing heat and flooding on overburdened and vulnerable populations
- Addressing the impacts of increasing average temperatures on forests, ecosystems, and wildlife
- Addressing the impacts of a warmer and wetter climate on agriculture
- Addressing the impacts of increasing average temperatures on recreation and tourism
- Addressing the impacts of landslides on built infrastructure

Addressing the Impacts of Increasing Heat and Flooding on Health

Impacts

Increasing average temperatures and more frequent and intense heat waves, flooding, and storm events can cause significant human health risks. The following heat-related health risks were identified in the 2021 Impacts Assessment:

- Increased heat-related morbidity (e.g., heat exhaustion or stroke) and mortality
- Hazardous outdoor work, recreation, or exercise, particularly in urban areas
- Reduced outdoor air quality (e.g., due to higher ground-level ozone and allergen levels)
- Increased prevalence of vector-borne diseases (e.g., Lyme disease)
- Increased health risks related to harmful algal blooms on bodies of water
- Increased mental health impacts, including aggression, hostility, violence, and suicide
- Compromised birth outcomes
- Reduced ability to work productively
- Power outages or brownouts due to increased energy demand for cooling and associated risks.

Key Actors

- **State agencies (e.g., Department of Health, PEMA):** Can provide funding, support collaboration and coordination, and elevate key voices (e.g., researchers, local departments of health, community leaders) to support public health with climate hazards in mind.
- **State legislature:** Guided by experts, the Commonwealth's legislature can increase funding and revise policies, planning, and leadership mechanisms to advance climate-related public health priorities.
- **Municipalities:** Local health departments can implement and/or pilot Department of Health programs (e.g., training) in coordination with community organizations and other municipal agencies.
- **Researchers:** Can monitor public health metrics associated with climate hazards, in coordination with community organizations and departments of health.
- **Community-based organizations:** Organizations that advocate for public health or facilitate community networking and communication may support needs such as outreach and information gathering.

Populations with underlying physical or mental health conditions, populations in areas with significant urban heat island effects, and many marginalized, aging, and low-income populations may be more vulnerable to these impacts.

Intense precipitation and inland flooding can also cause significant human health risks, particularly related to flash-flood events and water pollution. The following flood-related health risks identified in the 2021 Impacts Assessment include:

- Physical safety risks from flood waters or limited access to critical services
- Road accidents due to reduced visibility and hazardous driving conditions
- Reduced water quality and associated impacts (e.g., illness from drinking contaminated water)
- Compromised birthing outcomes
- Loss of power and associated risks
- Mental health impacts.

Health and safety impacts of flooding will vary according to the type of land flooded. For example, flooding on poorly protected toxic waste sites or agricultural lands could lead to higher chances of hazardous materials escaping into the environment. Low-income populations tend to live near these areas and may be more vulnerable to these impacts than the general population.

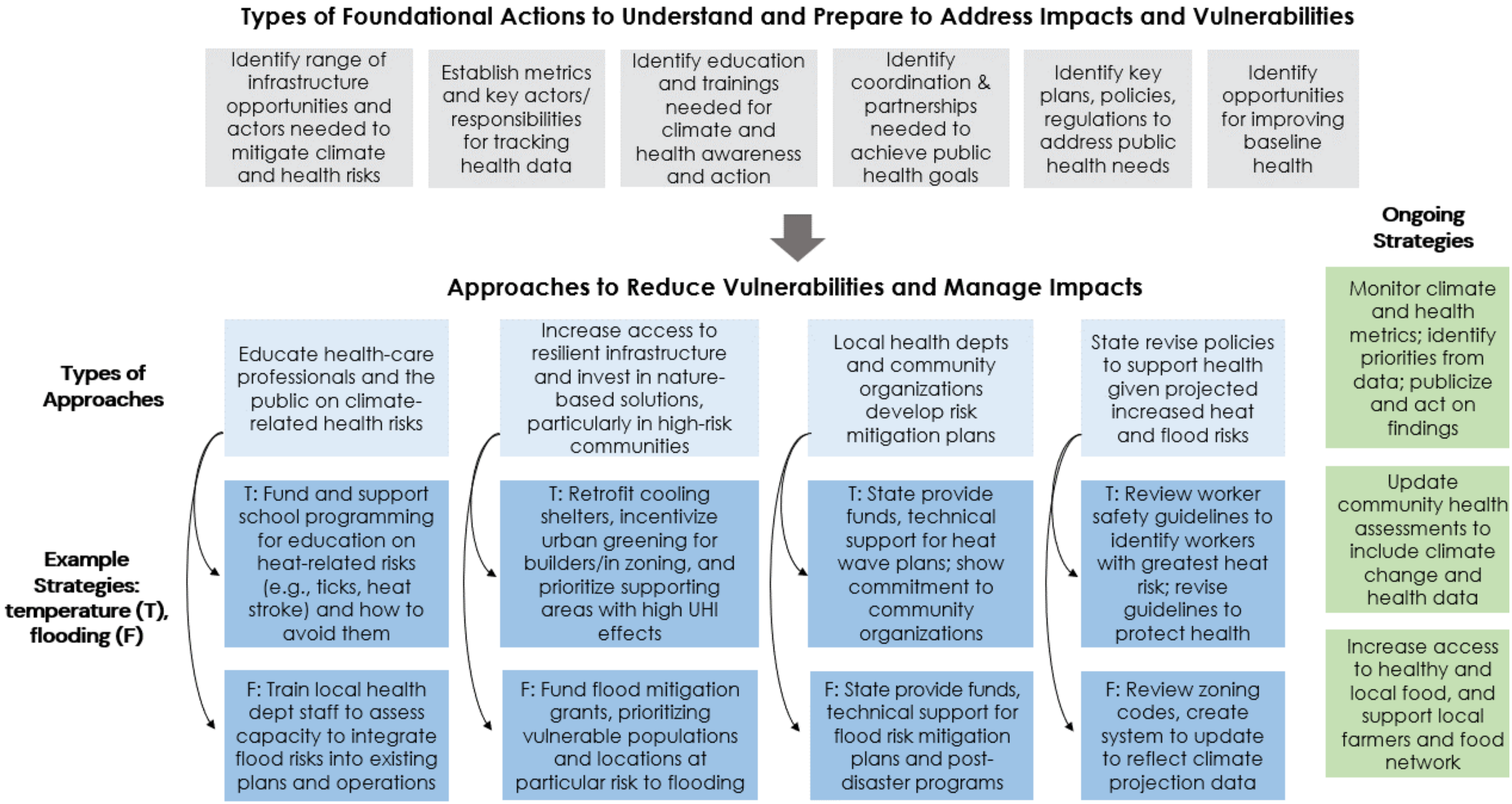
Adaptation Strategy Pathway

Adaptation strategies can be used to target the underlying causes of vulnerability and the resulting impacts. The Commonwealth must first establish climate change-related public health metrics; specify education and training, coordination, and policy/planning needs; and create baseline health improvement opportunities to support public health in a changing climate.

After these first steps, Pennsylvania can pursue various strategies to manage the impacts of increased temperatures and flood events, reduce health stressors, and enable communities, government and business systems, and infrastructure to adapt to the changing climate.

Figure 33 outlines the types of strategies that can be implemented to identify, manage, and address the impacts of heat and flooding on human health in the Commonwealth. Pennsylvania could also pursue other early strategies that may be straightforward and easily accomplished. Many public health strategies will help the Commonwealth adapt to both heat and flooding risks; these dual-purpose strategies are indicated in blue. Strategies specific to addressing heat or flood hazards begin with a T: or F:, respectively

Figure 33. Adaptation strategy pathway to reduce public health impacts from heat and flooding



This diagram provides illustrative examples of the primary types of strategies but does not capture the full universe of possible strategies that could be deployed. Strategies specific to addressing heat or flood hazards begin with a T: or F:, respectively.

How strategies are sequenced—which are implemented first and second, and where the thresholds are that indicate the need for more aggressive actions—depends on state actors' understanding of impacts, the availability of decision-support tools, resources, and capacity.

For example, after identifying education and training needed for climate and health awareness and action, the Department of Health may be able to begin outreach to professionals who can develop the training immediately. But State and local departments of health, healthcare professionals, and climate science experts will have to work together to develop a foundation for trainings and then tailor versions for different audiences (such as healthcare providers, teachers and educators, and homeless shelter staff), which may be more time- and labor-intensive. Increased State funding or operational or programmatic revisions may also be needed. As a result, State action will depend on the availability and willingness of a variety of stakeholders to spend time on climate-hazard education.

State actors can build action plans from the suite of strategies available. Coordination among State leadership, the research community, and community-based organizations is critical to implementing action plans. Acting according to a shared vision will allow the State legislature, State agencies, and local governments to enable and build on one another's efforts.

Figure 34 outlines an example sequence of foundational actions and three strategies led or facilitated by State agencies that could be pursued to support public health work that integrates risks of climate change. Appendix C provides more strategies related to this area.

The Pennsylvania Department of Health (DOH) and county and municipal health departments already support a range of programs and resource centers focused on community health needs. For example, the DOH Community-Based Health Care Program[100] and School Health Program[101] provide health resources, and the Community-Based program provides grants for development, expansion, or improvement of community-based healthcare clinics. Additionally, state health centers[102] and county and municipal health departments[103] support public health through programs such as health education and community health leadership. These programs and departments can play key roles in developing and scaling up climate and health work focused on equity and community leadership.

---

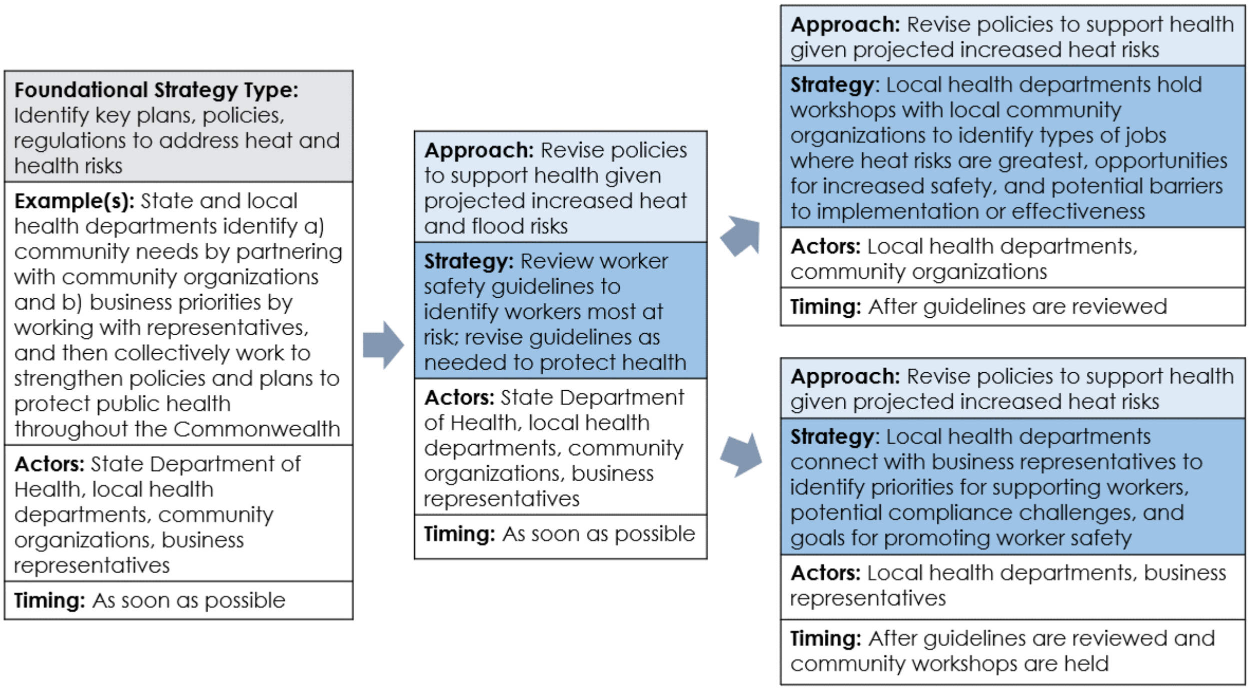
[100] Pennsylvania Department of Health. 2021. "Community-Based Health Care Program." https://www.health.pa.gov/topics/Health-Planning/Pages/Community-Based-Health-Care-Program.aspx

[101] Pennsylvania DOH. 2021. "School Health." https://www.health.pa.gov/topics/school/Pages/School%20Health.aspx

[102] Pennsylvania DOH. 2021. "State Health Centers." https://www.health.pa.gov/About/Pages/State%20Health%20Centers.aspx

[103] Pennsylvania DOH. 2021. "County and Municipal Health Departments." https://www.health.pa.gov/About/Pages/County-Municipal%20Health%20Depts.aspx

Figure 34. Example set of strategies to be pursued to support public health impacts of increased average temperatures and heat waves



Costs and Benefits

In supporting the health of the Commonwealth's population, these strategies could have co-benefits ranging from saving lives to reducing healthcare costs. Many strategies may also have other economic benefits, such as reduced energy costs and improved livability and desirability of certain neighborhoods (and the associated increase in property values and tax base). For example, strategies to reduce the urban heat island (UHI) may have up-front costs but significant return on investment. One study on the costs and benefits of tree planting and maintenance in five cities found that "on a per tree basis, cities accrued benefits ranging from roughly $1.50 to $3.00 for every dollar invested," with cities spending $15 to $65 per tree each year and accruing $30 to $90 in benefits per tree each year (e.g., increased property values, improved stormwater control, improved air quality).[104]

These co-benefits will be particularly beneficial given the chance of increased operational costs to support health and safety needs under future conditions. "Growing Stronger: Toward a Climate-Ready Philadelphia" found a higher "everyday cost of doing business" projected for city government, businesses, and residents from hotter temperatures and increased

[104] U.S. Environmental Protection Agency (EPA). 2008. "Trees and Vegetation." In: *Reducing Urban Heat Islands: Compendium of Strategies. Draft.* Available at: https://www.epa.gov/heat-islands/heat-island-compendium.

precipitation. For example, climate change could double or almost triple the annual cost (now about $20,000) of running the Heatline, a helpline the city provides during heat emergencies.[105]

CASE STUDY

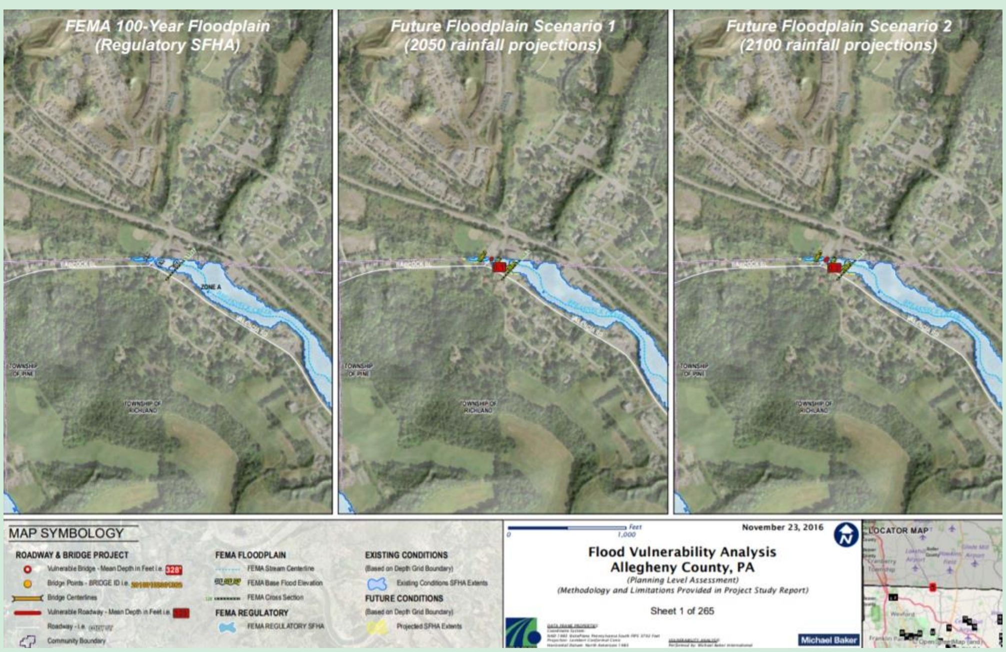
Implementing Strategies at PennDOT to Manage Flood Risks, with Health and Safety Benefits

Two health risks associated with extreme flooding involve transportation: physical safety risks from floodwaters or limited access to critical services, and road accidents due to reduced visibility and hazardous driving conditions. Maintaining and designing flood-resilient transportation systems is foundational to mitigating physical safety and health risks related to reduced transit access or road accidents from flood events.

The Pennsylvania Department of Transportation (PennDOT) Phase 1 Extreme Weather Vulnerability Study,[106] which PennDOT developed in 2017, provides an example of how climate data can be used to assess future flood hazard risks to transportation infrastructure and develop resilience strategies, many of which support safer roads and thereby reduce health risks related to flooding.

To evaluate future climate impacts on flooding, PennDOT studied global climate model projections and developed flood forecast zones that integrated future climate data to study how stream depths might change and affect transportation infrastructure in three counties (Allegheny, Delaware, and Lycoming) (see Figure 35).[107]

Figure 35. Future flood forecast maps. Taken from PennDOT, 2017a.



---

[105] Philadelphia Mayor's Office of Sustainability and ICF International. 2015. "Growing Stronger: Toward a Climate-Ready Philadelphia." https://www.phila.gov/media/20160504162056/Growing-Stronger-Toward-a-Climate-Ready-Philadelphia.pdf.

[106] Pennsylvania Department of Transportation (PennDOT). 2017. "Phase 1: PennDOT Extreme Weather Vulnerability Study – Study Report." http://s3.amazonaws.com/tmp-map/climate/doc/StudyReport-PaVulnerabilityStudy-ver040317.pdf.

[107] PennDOT, Phase 1: PennDOT Extreme Weather Vulnerability Study.

PennDOT identified resilience strategies in five categories: (1) planning, coordination and training; (2) data analysis and information sharing; (3) maintenance and inspections; (4) design; and (5) equipment, materials and technology.[108]

Example strategies include:

- Maintenance and Inspections:
    - Improve maintenance procedures and armoring of stream banks to prepare for potential increased flooding events in the future
    - Continue to expand and improve methods and procedures for pre- and post-flood inspections of roadways, bridges, and streams
    - Plan for increasing redundancy at roadway locations that may be impacted by storms (ensure secondary roads are maintained and available for use)
- Conduct stormwater management studies using a watershed approach including municipalities, PennDOT, and DEP.
- Design:
    - Identify updates to PennDOT design manuals based on national research and other university studies
- Program projects to improve stormwater capacity, reduce impermeability and ensure adequate maintenance of infrastructure
- Work with municipalities to identify the impacts of development on stormwater management
- Identify facilities requiring design upgrade in advance of funding requests.[109]

Additional information can be found on the Extreme Weather Vulnerability Study site.[110]

The Philadelphia Beat the Heat program is an example of addressing the health impacts of increasing heat. This program is highlighted as a case study in the next section.

Addressing the Impacts of Increasing Heat and Flooding on Overburdened and Vulnerable Populations

Impacts

Warmer temperatures and increased flood risk are expected to disproportionately impact overburdened and vulnerable populations. These populations may both be more at risk to impacts from these hazards and face greater challenges in managing those risks.

The following factors may increase vulnerability to heat and flood risk:

- Demographics (e.g., older age, minority race or ethnicity)

---

108 PennDOT, 2017a.

109 PennDOT, 2017.

110 PennDOT. 2019. Extreme Weather Vulnerability Study. https://pennshare.maps.arcgis.com/apps/MapSeries/index.html?appid=29bf9f06045f47feb9888193674f8a95

- Limited English proficiency
- Low income or wealth
- Physical or mental disability (e.g., requiring support to walk or communicate needs)
- Food insecurity
- Limited mobility (e.g., limited access to vehicles and/or public transportation)
- Type of employment (e.g., outdoor labor job)
- Distrust of government and media information sources.

Due to the hazards' different impacts, certain populations may also be at greater risk for each hazard.

Populations most at risk to high heat include those that are particularly susceptible to heat illness (e.g., older adults or people with cardiovascular disease) and those that disproportionately lack access to ways of adapting to heat, hazards, such as using air conditioning indoors (cost may be a barrier), staying in the shade outdoors (outdoor work and financial constraints may be a barrier), or drawing on support networks (seniors living alone may be especially vulnerable).

Populations most at risk to flood hazards are those that may be disproportionately exposed to the hazards and/or have greater barriers to managing them. For example, unhoused people, low-income people (e.g., those living in a home located in a floodplain or near toxic sites or hazardous facilities; those who cannot afford flood insurance), people who work outside (e.g., in the agricultural or construction sector), and communities of color that face historical disinvestment (e.g., aging and degraded infrastructure) may be more at risk to impacts.

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, due to factors such as 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.

Overburdened populations—"Minority, low-income, tribal, or indigenous populations or geographic locations … that potentially experience disproportionate environmental harms and risks." EJ areas are used in this assessment as a proxy for locations where populations are already overburdened by hazards and other structural disadvantages.

Pennsylvania DEP has identified Environmental Justice (EJ) areas as census tracts where at least 20% of the population is living at or below the poverty line and/or at least 30% of the population identifies as a non-white minority.[111] The 2021 Impacts Assessment evaluated the spatial overlap between EJ areas and areas exposed to climate hazards and found EJ areas were more exposed to extreme heat and flooding risks compared to the state overall. Specifically, EJ

[111] Pennsylvania Office of Environmental Justice. N.d. "PA Environmental Justice Areas." https://www.dep.pa.gov/PublicParticipation/OfficeofEnvironmentalJustice/Pages/PA-Environmental-Justice-Areas.aspx

areas are 1.8 times as exposed to high numbers of high-heat days and are slightly over-represented in high-risk flood zones, compared to the state overall.

Adaptation Strategy Pathway

Various adaptation strategies can be deployed to target these drivers of vulnerability. Any such strategy will require many actors (see box)—including the Office of Environmental Justice (OEJ), the legislature, municipalities, community-based organizations, and researchers—to collaborate with community-based organizations to assist in strengthening communities.

Early foundational strategies to enable adaptation include identifying community-based organizations to partner with and working with the community-based organization on establishing metrics to track vulnerability and progress. With this foundation, various strategies can be pursued to manage potential inequitable impacts of climate change.

State agencies and the legislature will likely primarily provide support and resources (e.g., coordination, facilitation, technical assistance, funding) to advance environmental justice in the context of climate hazards.

Key Actors

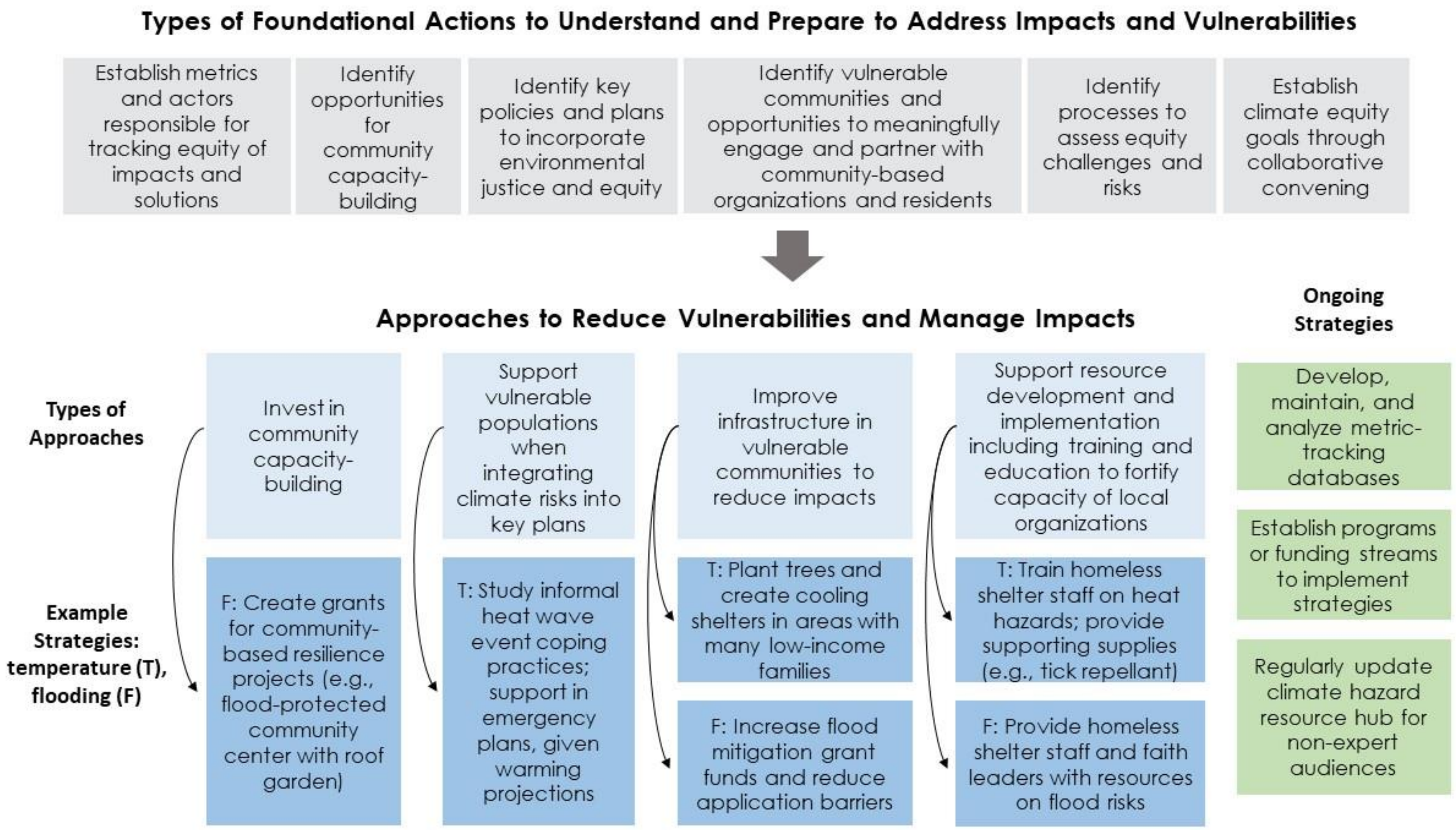
- **State agencies, specifically OEJ:** This Office works to ensure that Pennsylvanians most at risk from pollution and other environmental impacts have a voice in the decision-making process, and live in sustainable communities by minimizing adverse environmental impacts, supporting community empowerment, and fostering economic opportunities.
- **State legislature:** The Commonwealth's legislature can increase funding and support, and revise policies, planning, and leadership mechanisms, to advance climate justice priorities.
- **Municipalities:** Local governments can connect community-based organizations and leaders with officials managing climate planning processes.
- **Community-based organizations:** Organizations that represent communities in EJ areas and vulnerable populations may lead, advise on, and advocate for certain changes.
- **Researchers:** Academia (e.g., colleges and universities) and the broader research community can provide research, tools, and critical subject area expertise around climate issues to aid communities and government in advancing climate planning for vulnerable populations.

Community-based organizations and residents' input, climate science, and expertise from researchers and OEJ can inform data collection, operations, and processes that can either mitigate or exacerbate the impacts of climate hazards on vulnerable populations and in EJ areas. From there, the State, municipalities, researchers, and the science and business communities can work with community stakeholders to assess how they might alter their practices in the near, mid-, and long terms.

Figure 36 outlines some foundational actions and types of strategies that can be deployed over time to identify, manage, and address potential equity impacts from climate hazards.

The sequencing of strategies depends on state actors' understanding of impacts, the availability of decision-support tools, resource availability, and capacity.

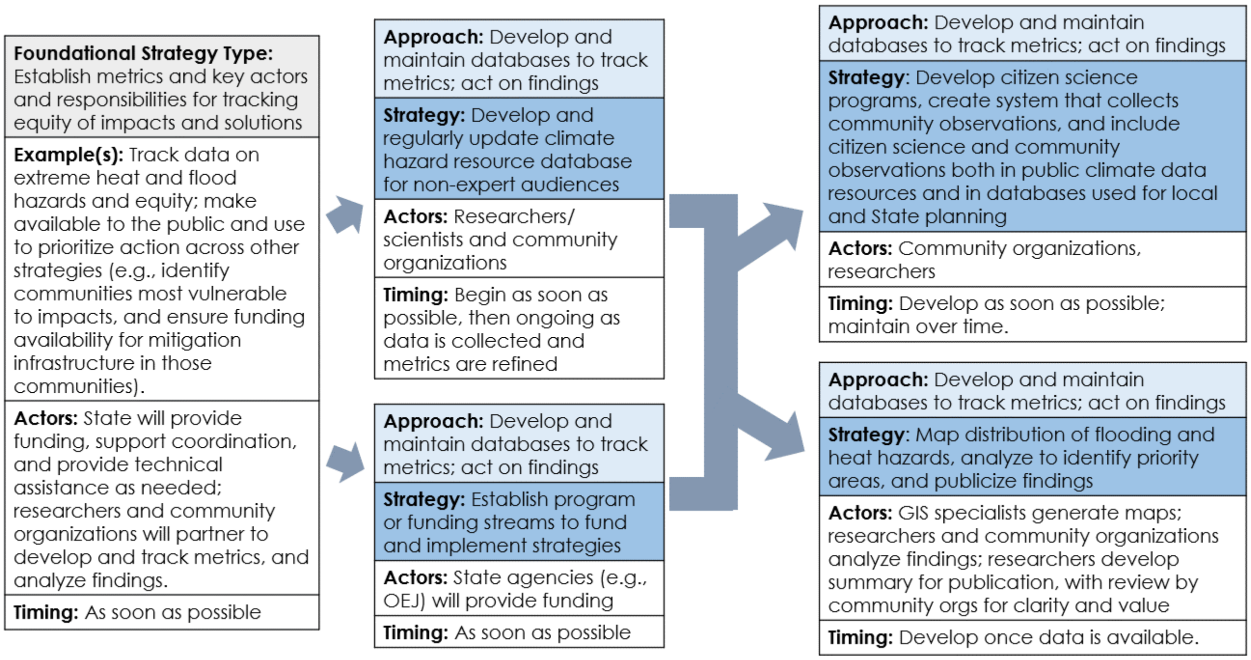
Figure 36. Adaptation strategy pathway to reduce increased hazard impacts of high temperatures and flood on overburdened and vulnerable populations



This diagram shows the primary types of strategies but does not capture the full universe of possible strategies that could be deployed. Strategies specific to addressing heat or flood hazards begin with a T: or F:, respectively.

Figure 37 outlines an example sequence of foundational actions and three strategies initiated or co-facilitated by state agencies that could be pursued to support environmental justice work in the Commonwealth. Appendix C provides more strategies related to this priority area.

Figure 37. Example set of strategies to be pursued to support climate justice and counteract equity challenges resulting from increased average temperatures (top) and flooding (bottom)



For example, after establishing metrics and determining the key actors responsible for tracking the equity of climate hazard impacts and adaptation solutions, the DEP can work with a range of stakeholders, including community partners, and immediately begin to develop databases with information pertinent to designing and prioritizing adaptation measures (e.g., data on which populations and areas may be experiencing disproportionate impacts of hazards). Increased State funding and other additional implementation resources will probably be needed, however, for implementation of citizen science programs and development of a community-observation data collection system. DEP actions will therefore depend on resource availability and establishing relationships with community-based leaders to spend time on building this collective climate hazard work.

A collective process is key to building climate equity action plans from the range of strategies available; community-based organizations, researchers, OEJ, the State legislature, and municipal governments will all be critical in plan design and implementation. Acting according to a shared vision will allow all actors to enable and build on one another's efforts.

Costs and Benefits

Strategies in this priority area will promote equity and they often will have cross-cutting co-benefits. For example, developing relationships to facilitate community engagement and education for purposes of emergency planning may lead to a better understanding of and support for local needs at a government level. Increasing the availability of funds for community resilience grants—for example, for development of an elevated park, with permeable surfaces to manage nuisance flooding, in a predominantly low-income neighborhood—could lead to new or improved amenities (e.g., the park) that beautify and revitalize neighborhoods, and may increase social cohesion.

The benefits of strategies in this section should be evaluated in terms of the "triple bottom line," where economic, social, and environmental costs and benefits are all considered. Costs of inaction or uninformed adaptation may lead to severe social and environmental costs; the immense human and natural benefits of adaptation must be included in the equation.

Notably, infrastructure strategies may require significant up-front costs, while strategies for education and community development may require lower costs over a longer timeline. Some costs may be shouldered primarily by a single actor, while others, especially those resulting in multiple benefits or that support the goals of multiple funders, may be shared among those stakeholders. For example, education on weatherizing homes to manage heat could be funded by departments of health, energy stakeholders, and property management actors.

CASE STUDY

A Community-Driven Approach to Tackling Heat in Philadelphia

In 2018, the Philadelphia Office of Sustainability (OOS) focused on integrating explicit considerations of equity in the implementation of Greenworks, Philadelphia's sustainability plan, and launched the Beat the Heat initiative as a step in this direction.

The updated Greenworks vision takes a community-driven approach to address impacts of heat, including:

- Acknowledging that environmental inequalities, like exposure to heat, often exist in majority low-income neighborhoods and neighborhoods of color in Philadelphia
- Working to understand how the City's systems, policies, and procedures might create barriers that maintain these inequalities
- Redirecting City resources towards dismantling these barriers.[112]

OOS also promised to implement two key strategies to reduce environmental justice issues around heat risks: (1) to intentionally "use its data to identify disparities" around heat risks, and (2) to "directly engage with communities" not experiencing the benefits of existing sustainability initiatives.[113]

For example, the Philadelphia OOS and Department of Public Health developed the Philadelphia Heat Vulnerability Index,[114] which integrates average surface temperature data with census data and demonstrates a "pattern of unequal exposure," with residents of color and low-income residents disproportionately exposed to hotter temperatures. The Beat the Heat initiative draws on the data

---

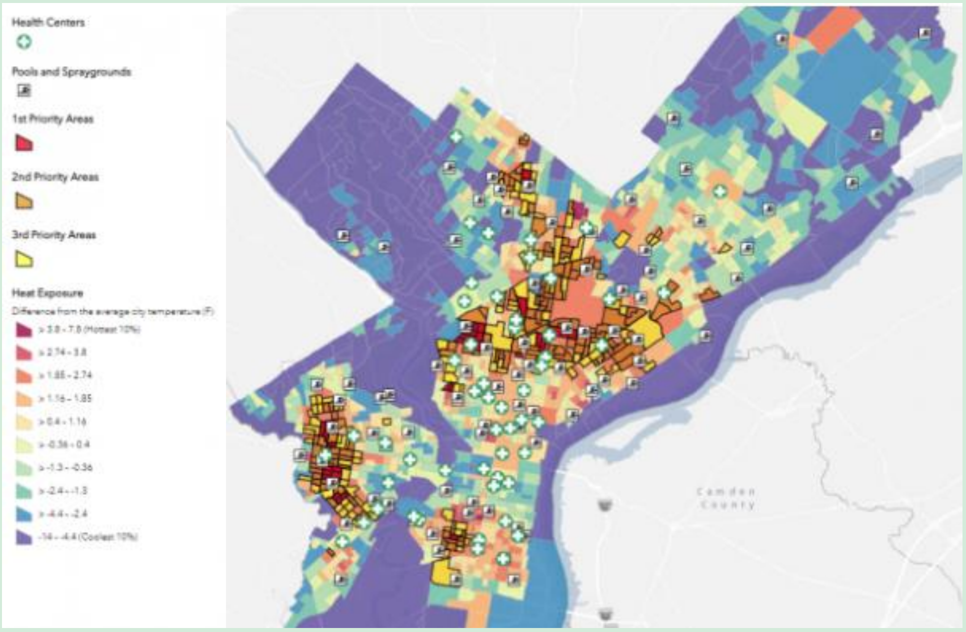
112 Philadelphia Office of Sustainability (OOS). 2019. "Beat the Heat Hunting Park: A Community Heat Relief Plan." https://www.phila.gov/media/20190719092954/HP_R8print-1.pdf.

113 OOS, 2019. "Beat the Heat Hunting Park."

114 Kellner, Hans. July 16, 2019. "Heat Vulnerability Index highlights City hot spots." https://www.phila.gov/2019-07-16-heat-vulnerability-index-highlights-city-hot-spots/

from this Index to support the communities identified as disproportionately exposed and vulnerable to environmental stressors like extreme heat.

Figure 38. Philadelphia Heat Vulnerability Index map



Source: Hans Kellner. July 16, 2019. Heat Vulnerability Index highlights City hot spots.

For the Initiative's pilot, the city convened the interdisciplinary Heat Team to work with community leaders and residents in Hunting Park, one of Philadelphia's "hottest and most heat vulnerable" neighborhoods, to identify root causes of heat disparities in Hunting Park and support "community-driven decision-making about how to reduce these inequities."

Community engagement included workshops, participation in community events, direct work with community leaders, and a neighborhood heat survey.

The following strategies emerged from this community engagement:

- Continue to implement projects that support cooling in Hunting Park, including additional tree plantings and the installation of green stormwater infrastructure.
- Review city policies related to land use, green infrastructure, transportation, and outreach to consider how they might address heat.
- Launch a Hunting Park Heat Relief Network in the summer of 2019.
- Share the Beat the Heat Toolkit with other heat-vulnerable communities.
- Develop a citywide climate adaptation plan to understand how climate change will impact different areas of the city and to begin planning how to mitigate those impacts.
- Identify better ways to communicate about heat and cooling resources, including establishing a city heat website to make it easier for residents to find cooling resources.[115]

This initiative shows what equity-focused heat initiatives could look like and the importance of having community voices take a leading role in equitable climate change adaptation planning.

[115] OO., 2019. "Beat the Heat Hunting Park."

Additional information can be found in Beat the Heat Hunting Park: A Community Heat Relief Plan.

Figure 39. Members of the community attending the Beat the Heat Neighborhood Design Workshop

Source: OOS, 2019. "Beat the Heat Hunting Park."

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

Impacts

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. The following drivers and vulnerabilities that will particularly harm forests, ecosystems, and wildlife were identified in the 2021 Impacts Assessment:

- 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 Delaware estuary
- Increases in algal blooms.

Adaptation Strategy Pathway

Various adaptation strategies can be deployed to target these drivers and vulnerability areas. First, the Commonwealth must identify and prioritize species and ecosystems to protect and support as temperatures warm. Pennsylvania could also pursue other early strategies that may be straightforward and easily accomplished.

After this evaluation and selection, Pennsylvania can pursue strategies 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. Figure 40 outlines the types of strategies that can be deployed in sequence to identify, manage, and address the impacts of increased average temperatures on the Commonwealth's forests, ecosystems, and wildlife.

The sequence of strategies depends 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 harm critical tree species. But DCNR may need to wait for funding or capacity to work on ecosystem restoration or forest connectivity. As a result, DCNR action might depend on the state legislature's pursuit of new policies or increasing funding.

Key Actors

State agencies: These agencies are responsible for promoting environmental and ecosystem health in the Commonwealth. Relevant natural resource agencies include DEP, DCNR, PA Game Commission, and PA Fish and Boat Commission.

State legislature: The Commonwealth's legislature can increase funding and supports to enhance the resilience of the State's natural resources.

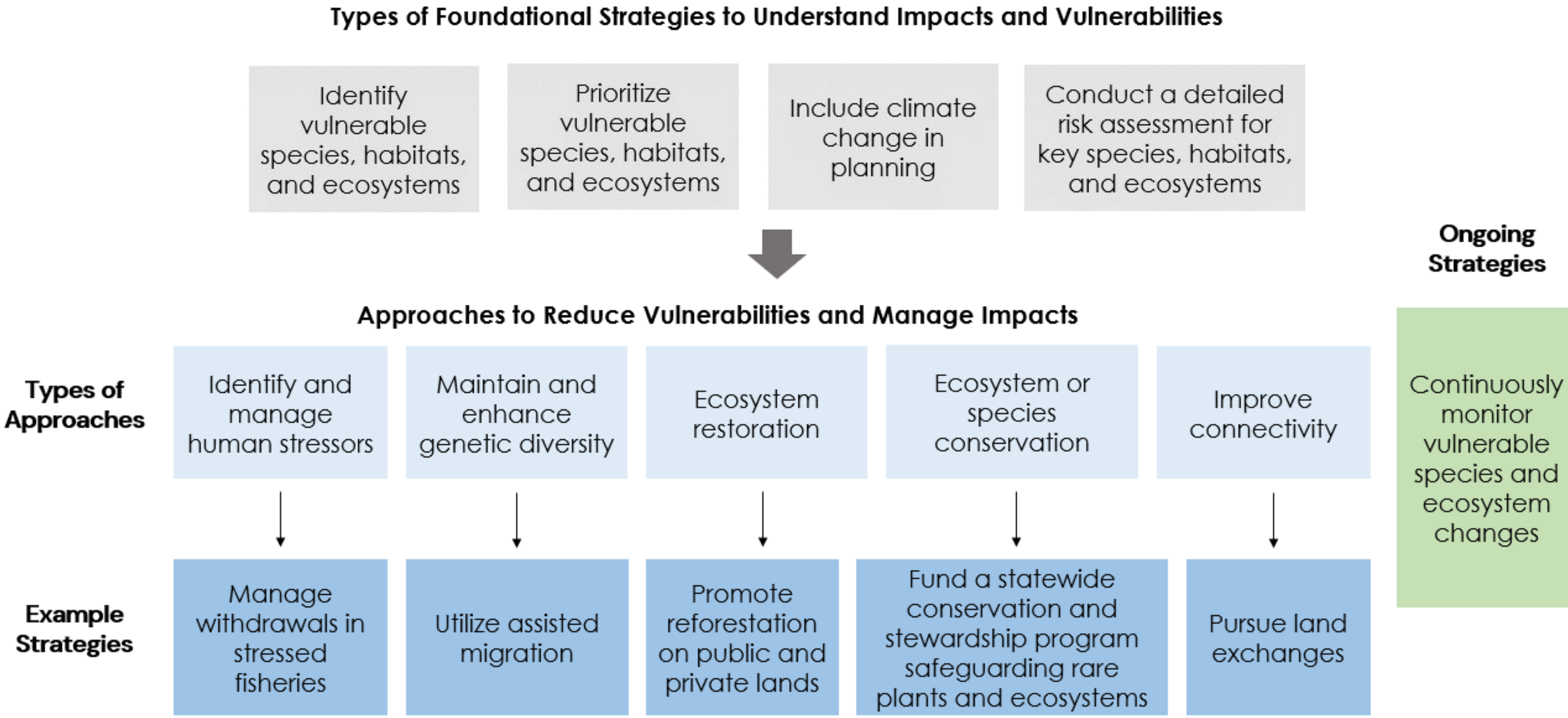
Municipalities: Local governments may operate nature preserves and/or areas with protected natural resources.

Conservation organizations: These groups lead many restoration and conservation efforts in the Commonwealth.

Federal agencies: Several agencies (e.g., National Park Service, Environmental Protection Agency) hold lands in Pennsylvania and/or are generally responsible for preserving the U.S.'s ecosystem health and natural resources.

As action plans are developed, state actors can build action plans from the range 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 41 outlines a sequence of four strategies led by state agencies that could be pursued to support vulnerable forests in the state. Appendix C. provides more strategies for this area.

Figure 40. Adaptation strategy pathway to reduce increased average temperatures impact on forests, ecosystems, and wildlife



This diagram provides an illustrative example of the primary types of strategies but does not capture the full universe of possible strategies that could be deployed.

Figure 41. Example set of strategies to support forests vulnerable to increasing average temperatures.

Foundational Strategy Type: Identify vulnerable species, habitats, and ecosystems

Strategy: Conduct a more detailed risk assessment across key species, habitats, and ecosystems in the state

Actor: State Agencies, most likely DCNR

Timing: As soon as possible

Ongoing Strategy Type: Monitor vulnerable species and ecosystem changes

Strategy: Establish a statewide monitoring and research network to establish baseline conditions and monitor ecosystem factors.

Actor: State agencies, most likely DCNR and/or DEP

Timing: Ongoing beginning after vulnerable species and ecosystems are identified

Approach: Improve connectivity

Strategy: Promote connectivity by using land exchanges and conservation easements to allow species to migrate to suitable habitats

Actor: State agencies, most likely DCNR

Timing: As vulnerable areas are prioritized, and funding becomes available. Significant lead time may be needed to implement.

Approach: Ecosystem restoration and conservation

Strategy: Promote forest conservation, reforestation and urban tree canopy expansion on private and public lands

Actor: State agencies, most likely DCNR and/or DEP

Timing: After vulnerable areas are identified and prioritized

Costs and Benefits

Generally, the costs of strategies related to this priority area may range widely. Low-cost actions may build on existing programs, focus on education and outreach, or manage withdrawals. Higher-cost strategies may focus on developing areas for nature preserves or establishing reforestation programs. 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.[116] Providing funding for a low-cost action for plant conservation and ecosystem restoration would allow conservation of critical habitat for both plants and animals.

[116] Sources: https://waterlandlife.org/wildlife-pnhp/changing-landscapes/climate-change/ and https://waterlandlife.org/conservancy-protects-90-acres-laurel-highlands-along-great-allegheny-passage-casselman-river/.

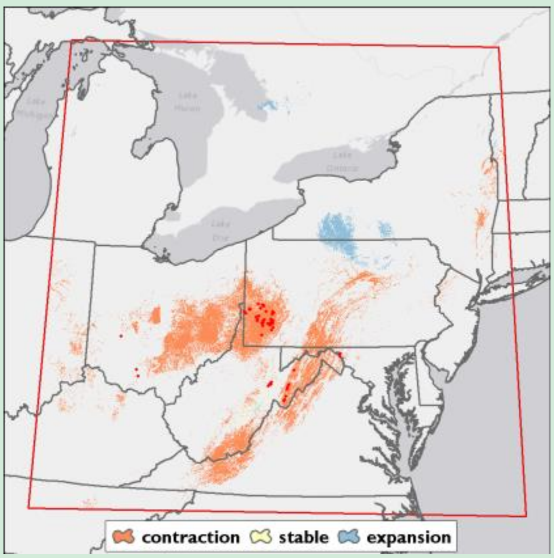
CASE STUDY

Identifying Species Vulnerable to Climate Change to Inform Adaptive Planning

In the Pennsylvania Natural Heritage Program (PNHP), DCNR works with the Western Pennsylvania Conservancy to collect and provide information on important ecological resources (e.g., wildlife, forest communities), including those affected by climate change. As part of this partnership, PNHP collects data on the State's ecological resources to help ensure the conservation of biological diversity across the Commonwealth.

PNHP uses a variety of tools to support conservation. For example, PNHP uses NatureServe's climate change vulnerability index (CCVI) to understand which species are most vulnerable to climate change. Using the CCVI, WPC found that the most vulnerable species are often those with a limited range and/or unique habitat needs.

Figure 42. Map of projected changes in the snow trillium flower species in 2060

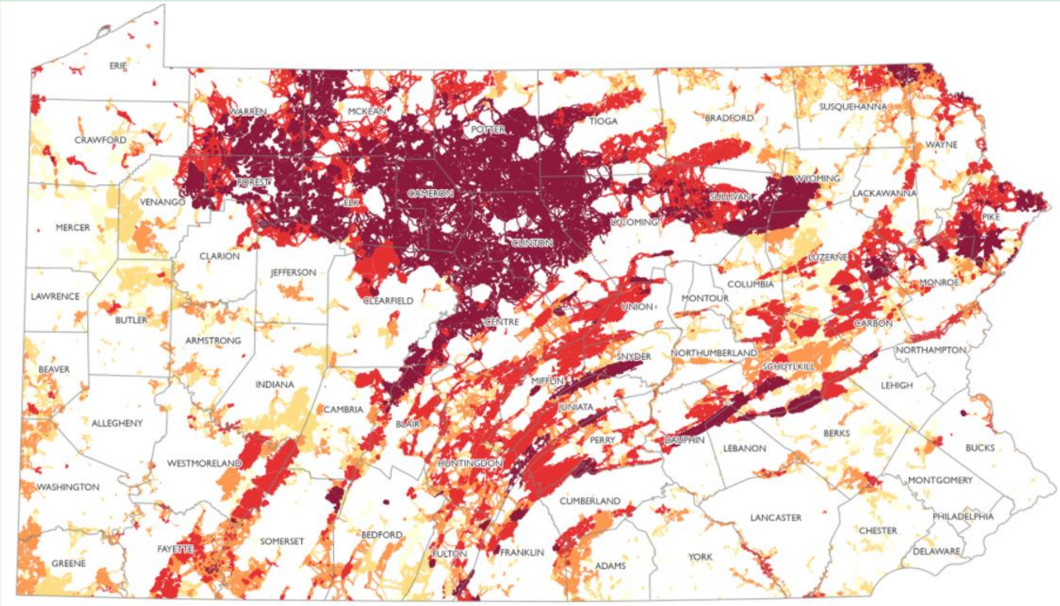


The map highlights that most of the flower species' suitable habitat will be lost by midcentury. Areas that will contract are in orange, those that will be stable are in yellow, and those that will expand are in blue.

As part of its broader effort to understand and monitor climate impacts on at-risk species and habitats, PNHP has also completed monitoring and modeling projects. For example, it used climate envelope modeling to understand how predicted climate change could affect the future distribution of a species. Figure 42 shows results from one modeling project that mapped the shifting habitat of the snow trillium flower. Through field-based monitoring, PNHP is also tracking potential climate change impacts in Pennsylvania's boreal wetlands—bogs and fens—where rare plants, birds, and invertebrates may be more sensitive to climate change.

PNHP's data gathering efforts are increasingly supporting DCNR's planning efforts. To make better informed planning decisions, DCNR recently enlisted PNHP to conduct a statewide analysis of corridor connectivity. The study prioritized locations for climate change connectivity conservation to help DCNR select sites for landscape-scale conservation. The results of the analysis provide insights for DCNR's strategic planning moving forward and serve as a powerful tool for conservation planning in the Commonwealth. Figure 43 highlights the mapped results of the analysis. More information on the study and its results can be found on its online story map.

Figure 43. Climate Change Connectivity Priority Scores identified in the PNHP study.



This map shows areas that are cores and connectors. Dark red represents those that are very high priority, bright red those that are high priority, dark orange those that are medium priority, light orange those that are priority, and light yellow those that are very low priority.

PNHP's climate change work has also pushed WPC to reshape its conservation planning process accordingly. WPC has taken a more informed and targeted approach in its planning process thanks to its improving understanding of climate change impacts on ecological resources. To incorporate climate change in its strategy for conservation and land protection and management, WPC has:

- Identified new guiding principles
- Revisited its conservation actions
- Detailed how climate change informed planning will change its work.

Ultimately, WPC aims to leverage this strategic vision and plan to protect Pennsylvania's critical future habitats and conserve the Commonwealth's ecological diversity as our climate changes. As part of this work, WPC has already started improving ecosystem resilience and connectivity in its land conservation efforts. The recent protection of 90 acres of land in the Laurel Highlands of Southwestern Pennsylvania serves as one example. WPC added the area to continue building a corridor of protected lands that could serve as contiguous and connected habitat for wildlife and plants. As it continues to expand this effort, WPC will aim to provide more suitable areas for species to adapt to the changing climate.

Addressing the Impacts of a Warmer and Wetter Climate on Agriculture

Impacts

Increased annual average rainfall, extreme precipitation, and average and extreme temperatures will alter many facets of agricultural management. For example, with climate change, crop yields are anticipated to shift, and nutrient leaching is likely to increase. The following potential vulnerabilities that will impact agriculture in the Commonwealth were identified in the 2021 Impact Assessment:

- Decreased crop yields
- Changes in crop planting and harvesting
- Altered growing seasons
- Increased runoff and erosion
- Augmented nutrient leaching
- Greater losses or damage to crops, equipment, and livestock
- Increased heat stress on livestock
- Increased volatility of local prices after extreme precipitation events
- Challenges to crop and nutrient management practices
- Reduced efficacy of pollution, nutrient, and sediment control strategies.

Adaptation Strategy Pathway

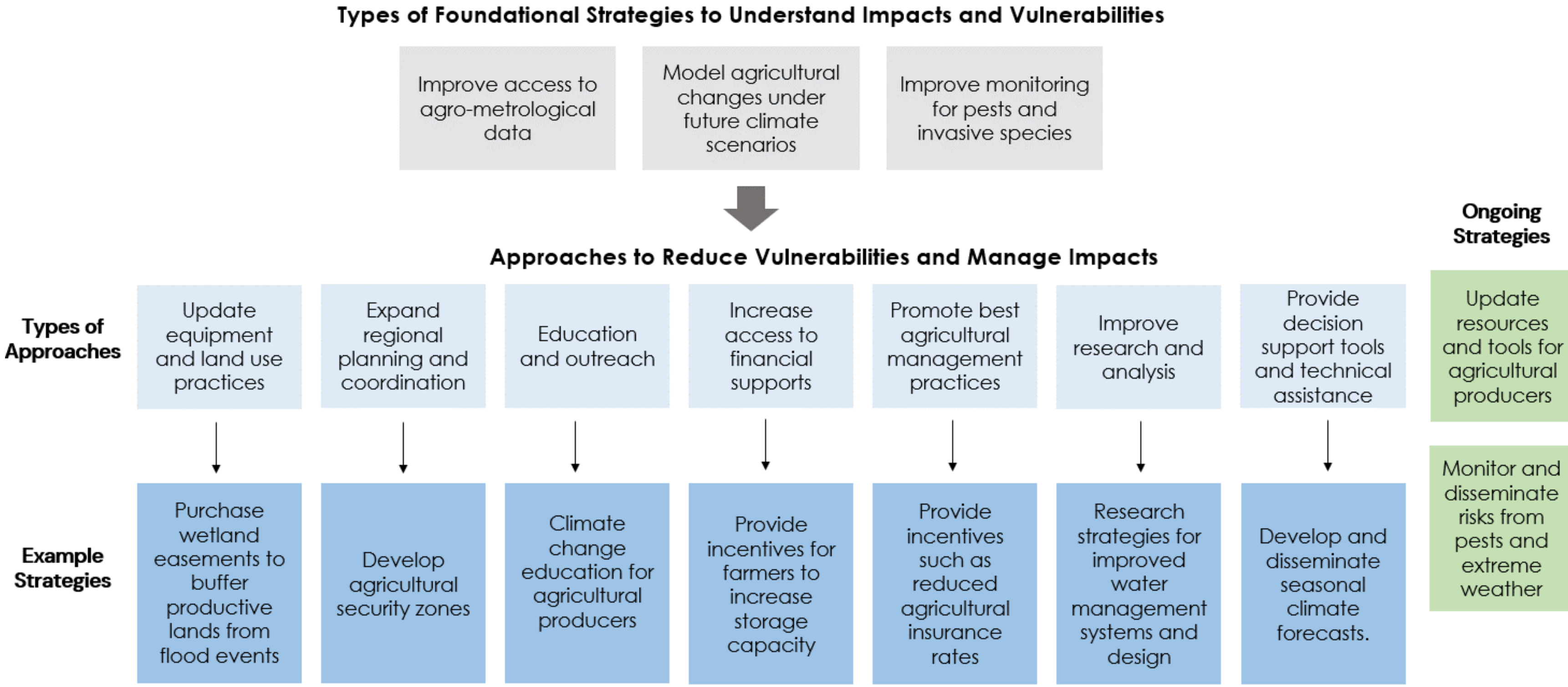
The Commonwealth's agricultural sector is already adapting to the changing climate. For example, no-till management and soil conservation practices implemented in recent years have reduced runoff rates in Pennsylvania. Continuing to adopt adaptive management practices will increase resilience and mitigate the impacts of a warmer and wetter climate.

Although individual farmers or agricultural producers will take most adaptation actions, government and universities can support the transition. First, these groups can work together to increase access to data on changing conditions. With this information, on-the-ground producers can improve their decision making and modify their practices as necessary. These actors can also provide useful resources, tools, and research to assist and encourage adaptation.

Figure 44 outlines the types of strategies that can be pursued to understand and adapt to the impacts of a warmer and wetter climate in agriculture. Many highlighted strategies target actors adjacent to the agricultural sector (e.g., universities, PDA). As the climate changes, updating information on risks, expanding available resources and tools, and reconsidering management practices will be necessary.

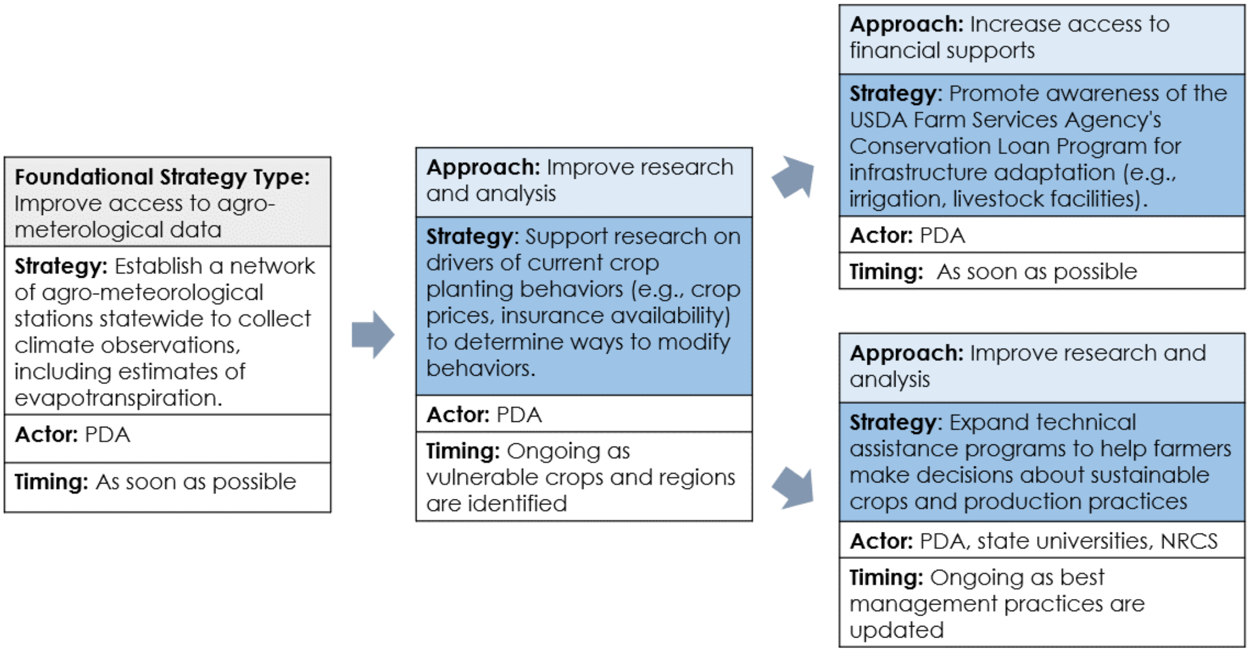
A wide range of support exists to advance adaptation in Pennsylvania's agricultural sector. Financial support, technical assistance, and research on changing conditions will be helpful in disseminating and encouraging best practices. Engaging and coordinating with stakeholders will help producers gain access to the resources they need to modify their practices. Figure 45 outlines a sequence of four strategies led by PDA, USDA, and state universities that could be pursued to support farmers. Appendix C provides more strategies related to this priority area.

Figure 44. Adaptation strategy pathway to reduce the impacts of a warmer and wetter climate on agriculture



This diagram provides an illustrative example of the primary types of strategies, but does not capture the full universe of possible strategies that could be deployed.

Figure 45. Example set of strategies to be pursued to support farmers vulnerable to a warmer and wetter climate



Costs and Benefits

Adaptation strategies in this sector will be time and potentially resource intensive. Updating funding and technical assistance programs will require significant human resources, but strategies in this pathway will be generally less costly than capital-intensive strategies like infrastructure improvements.

Although labor intensive, building resilience in this bedrock sector of the Commonwealth's economy will reap substantial benefits. Producers and farmers may be able to seize new opportunities as new crops become viable in the changed Pennsylvania climate. Modifying management practices to minimize pollution and runoff will also increase ecosystem and environmental health. Furthermore, mitigating climate impacts will bolster individual producers' prosperity and Pennsylvania's overall economic health and support rural communities.

CASE STUDY

USDA Northeast Climate Hubs

The USDA's climate hubs provide a wide array of information and resources on climate impacts to agriculture and on adaptation opportunities. The Northeast Hub aims to fill gaps and supply the needed resources for agricultural producers, including farmers and other stakeholders in Pennsylvania. The Northeast Hub collaborates with a range of organizations, including government agencies (e.g., U.S. Agricultural Research Service, U.S. Forest Service, Natural Resources Conservation Service (NRCS)) and land grant universities (e.g., Penn State). The hub highlights opportunities from partner agencies and research findings and tools from universities that can benefit producers as they adapt to a warmer and wetter climate.

For example, NRCS expanded the Environmental Quality Incentives Program to support adaptation and mitigation of the impacts of increasing weather volatility[117] and now offers funding for a wider scope of soil management practices (e.g., soil health conservation planning, soil testing, nutrient management, tillage management). The NRCS hopes to encourage efforts to improve soil health, which is "a key component for farm resiliency to long term changes in weather such as increased temperatures and increased rainfall."[118]

Similarly, the Northeast Hub spotlights initiatives and findings from partner universities like Penn State. Penn State researchers are investigating cropping practices that can be used on dairy farms to determine the best strategies for reducing erosion and minimizing the need for fertilizers and pesticides.[119] By highlighting resources from the university, the Northeast Hub connects producers to the latest findings on the best sustainable farming practices.

Through coordination and collaboration, the Northeast Hub has become a clearinghouse of climate adaptation information for agricultural stakeholders. The hub compiles tools, support mechanisms, and knowledge to help producers mitigate the impacts of climate change. The hub will continue to increase its offerings and leverage its partnerships to meet the changing needs of farmers.

Figure 46. A pasture in Pennsylvania [120]

[117] E. Marks 2020. "The USDA Natural Resources Conservation Service has expanded planning and funding related to climate smart farming practices for farms." USDA Northeast Climate Hub. https://www.climatehubs.usda.gov/hubs/northeast/news/new-nrcs-practices-address-climate-change-issues

[118] E. Marks. "Natural Resources Conservation Service."

[119] USDA Northeast Climate Hub. 2021. "Sustainable Dairy Cropping at Penn State." https://www.climatehubs.usda.gov/hubs/northeast/project/sustainable-dairy-cropping-penn-state

[120] USDA Northeast Climate Hub. 2021. "Sustainable Dairy Cropping at Penn State."

Addressing the Impacts of Increasing Average Temperatures on Recreation and Tourism

Impacts

Higher average temperatures are expected to impact recreation and tourism in the Commonwealth by driving changes in seasonal recreation activities and eliminating or reducing the feasibility of certain activities. Additionally, higher average temperatures could create hazardous conditions. The following drivers and vulnerabilities that will harm recreation and tourism were identified in the 2021 Impacts Assessment:

- Reduction in viability of snow- and ice-based recreation
- Seasonal shifts in recreational activities, such as extending summer outdoor activities into the spring and fall, or shifting activities away from summer months with very high temperatures (e.g., biking, golfing)
- Decreases in cold-water fishing opportunities
- Growth of water-based recreation in the summer
- Increases in algal blooms.

Adaptation Strategy Pathway

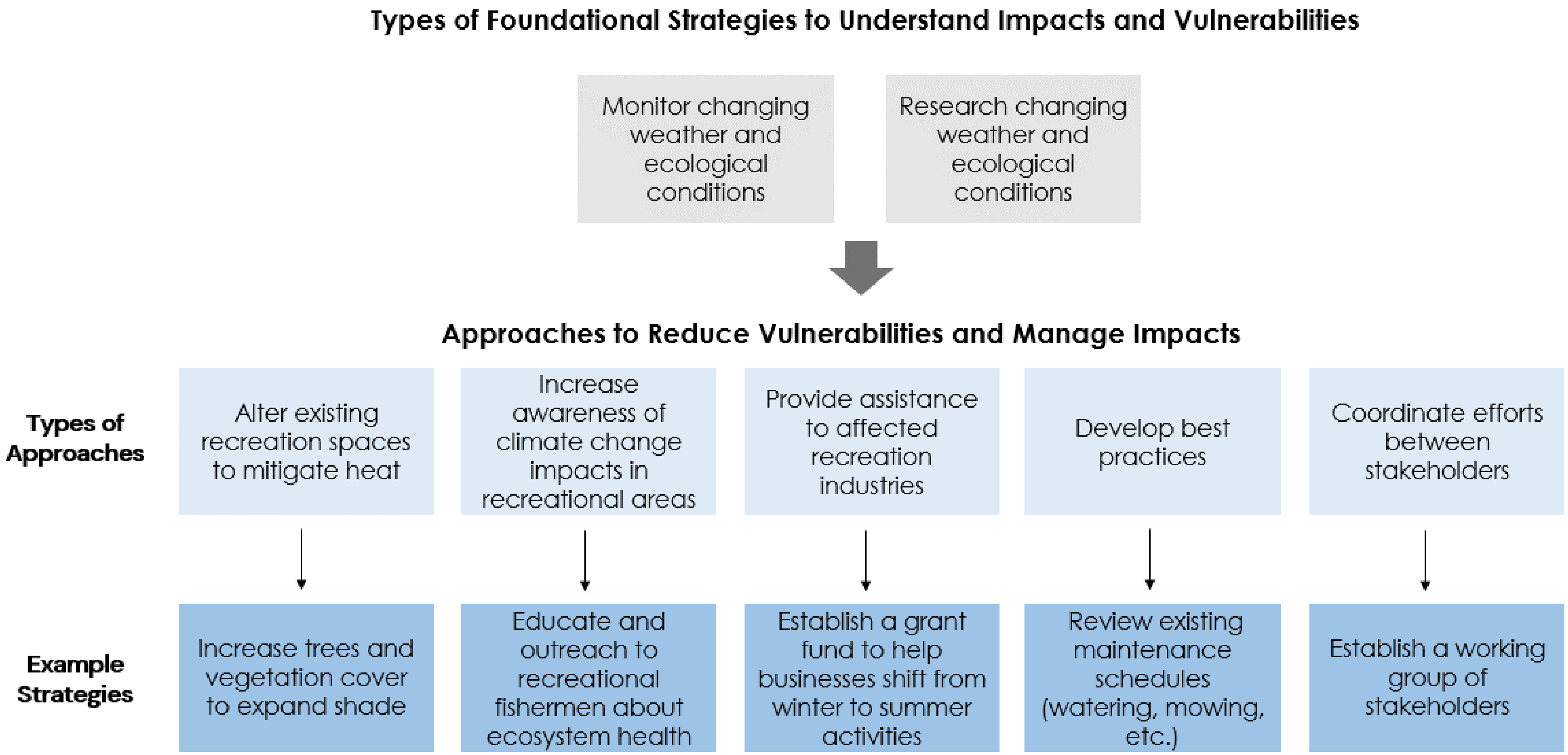
The Commonwealth must improve its understanding of how different industries in the tourism and recreation sector will be affected by higher temperatures. Researching and monitoring how weather and ecological conditions will affect recreation and tourism is a critical first step. Data gathering will help stakeholders (e.g., winter ski resort operators, DCNR) understand the rate at which changes will affect their services, operations, and facilities. With this information, stakeholders can plan for how quickly they must adapt to warming temperatures and pursue steps to manage impacts.

Opportunity for Cross Sector Coordination: Climate monitoring for weather, pests, and other ecological conditions can be pursued across sectors. For example, the agriculture, natural resources, and recreation and tourism sectors will all be interested in water quality monitoring.

Adaptation may take the form of improving recreational areas, encouraging industries to change their practices, and adapting recreational practices to be viable in the long term. Many strategies will not only mitigate consequences, but also capitalize on opportunities to expand offerings in Pennsylvania’s recreation and tourism sector.

Figure 47 outlines the types of strategies that can be deployed in sequence to identify and adapt to the impacts of increased average temperatures on the Commonwealth’s recreation and tourism sector. The order in which strategies are deployed is dependent on actors’ understanding of impacts, the availability of decision support tools, and funding.

Figure 47. Adaptation strategy pathway to reduce increased average temperatures impact on recreation and tourism



This diagram provides an illustrative example of the primary types of strategies but does not capture the full universe of possible strategies that could be deployed.

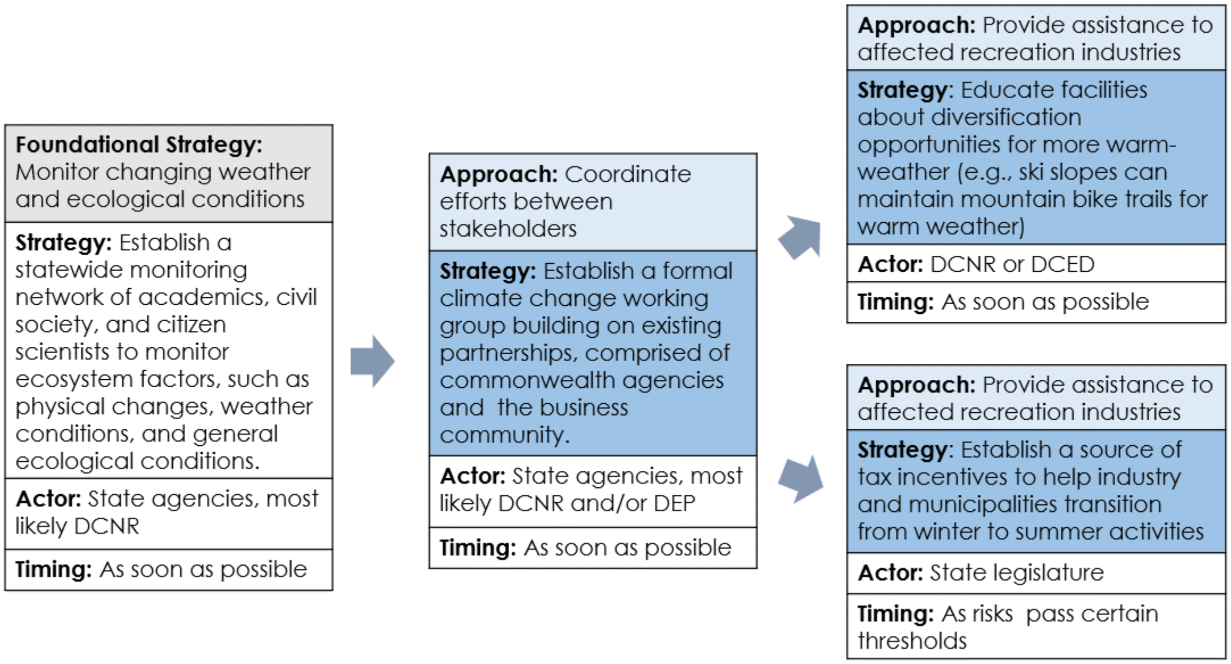
A variety of stakeholders will be impacted by changing recreational opportunities. Organizations that operate recreational facilities (e.g., DCNR, municipalities, businesses), will need to recognize how their revenue stream, operations, services, and/or facilities will change. With this information, stakeholders can then consider how to alter their management practices in the near, mid-, and long terms.

To support adaptation efforts, the state government, including DCNR, DCED, and the legislature, can provide support and resources (e.g., technical assistance, grants, loan programs) to facility operators and businesses. And with better understanding of impacts, including economic impacts such as lost revenue or jobs in winter recreation, municipalities and state leaders might target support to the groups most impacted. Figure 48 outlines a sequence of strategies that could be pursued by state agencies (DCNR, DCED) to support winter recreation businesses. Appendix C provides more strategies related to this priority area.

Key Actors

- **State agencies DCNR and DCED:** These agencies are responsible for promoting the recreation and tourism sector. DCNR also operates many recreational facilities.
- **State legislature:** The legislature can increase funding or make legislative changes to ease the adaptation process.
- **Municipalities:** Local governments can support businesses affected by increasing temperatures. Municipalities may also operate recreational facilities. Towns and cities may also experience changes in tax revenue if they depend on certain recreation centers such as winter ski resorts.
- **Business groups:** Industry groups that represent specific industries such as winter recreation sites and hotels may advocate for certain changes.
- **Individual businesses:** Some businesses may need to alter their services, operations, and/or facilities to remain viable or capitalize on new opportunities.
- **Recreation-based organizations**: Organizations and associations such as Trout Unlimited and the PA Cross Country Skiers Association can explore and advocate for adaptation solutions and support relevant industries in their adaptation efforts.

Figure 48. Example set of strategies to be pursued to support winter recreation businesses vulnerable to increased average temperatures



Costs and Benefits

Generally, strategies for this priority area could be costly but are investments in strengthening resilience. Other strategies, especially those that are foundational or non-intensive, will be less costly. For example, monitoring would be relatively inexpensive, while land acquisition, where needed, has high up-front costs. Investing resources in helping the sector adapt will help mitigate the economic consequences of increasing temperatures in the recreation and tourism industries.

Most significant adaptation techniques will require programs to improve recreation areas to better cope with warmer temperatures. These steps could include introducing new services, improving outdoor areas, retrofitting buildings, or updating equipment, or expanding existing offerings. State actions that support transformational actions may also be costly (e.g., technical assistance, grant programs), but should ultimately pay for themselves as they strengthen the economy's resilience. Some initial steps will require less resources (e.g., improving monitoring, education and outreach programs).

Overall, strategies in this priority area have the potential to have many co-benefits for the Commonwealth. Strategies may bolster economic resilience, promote overall environmental health (e.g., reducing overfishing in endangered fisheries), and support public health (e.g., increasing outdoor exercise opportunities). By creating more spaces that can be used for recreation throughout the year as temperatures warm, the Commonwealth can improve residents' quality of life and sustain Pennsylvania's economic health (i.e., increased jobs, rise in spending on recreation in warmer months).

CASE STUDY

Transforming Winter Ski Resorts

Pennsylvania has over 30 ski areas and thousands of acres of other land dedicated to winter recreation (i.e., ice fishing, cross-country skiing, snowmobiling). These areas are frequented by visitors from in-state and out-of-state.[121] But as winter temperatures warm, ski resorts will face a future filled with less and less snow or snowmaking conditions. The Commonwealth already experiences about a 12% reduction in visitors in lower-snowfall seasons compared to high-snowfall seasons.[122]

While ski areas will be severely impacted by warming temperatures, many opportunities exist to shift areas' uses and take advantage of the vast lands available for recreation. Many winter recreation areas have already updated spaces to provide multi-season attractions. With increasing temperatures, the Commonwealth can support the winter recreation industry in developing these areas for more multi-functional use.

Deploying Snowmaking and Snow Storage Techniques

Ski resorts are taking steps to prepare. Many have invested in snowmaking technologies to manage seasonal fluctuations in snow as winters have warmed.[123] In the short term, these investments can help mitigate reduced snowfall. Innovative techniques to increase access to snow in winter months could also be explored. Craftsbury Outdoor Center, which a cross country ski center in northern Vermont that provides open space for cross-country skiing, is trying snow storage. In 2019 in partnership with the University of Vermont,[124] to provide snow in November when there is insufficient natural snowfall, Craftsbury Outdoor Center produced 9,000 cubic meters of snow at the end of February and packed it densely and insulated it over the spring and summer. By November, 65% of the snow remained, which was enough to cover 2-3 km of trails. As natural snowfall becomes less common and the ski season shortens, the Commonwealth's ski industry and recreation centers with ski offerings can consider such new techniques.

Repurposing for Summer Recreation

Ski resorts have also invested in year-round recreation. By offering recreation opportunities in the spring, summer, and fall, the industry can boost visitors and maintain revenues. For example, Montage Mountain Ski Resort developed a zip line and outdoor water park to mitigate reduction in winter activity.[125] Seven Springs Mountain Resort and Blue Mountain Resort offer dozens of mountain biking trails to use their spaces in summer months.[126,127] Resorts in the Northeast have explored similar additions so that they can provide year-round offerings, such as mountain biking, all-terrain vehicle

[121] Unions of Concerned Scientists. 2008. Climate Change in Pennsylvania: Chapter 5 Impacts on Winter Recreation. https://www.nrc.gov/docs/ML0913/ML091390883.pdf.

[122] Burakowski, E., and Magnusson, M. 2012. Climate Impacts on the Winter Tourism Economy in the United States. Natural Resources Defense Council and Protect our Winters. https://www.nrdc.org/sites/default/files/climate-impacts-winter-tourism-report.pdf

[123] Kinney, J. 2015. "Weather woes: Can ski resorts Adapt to Climate Change?" Blue Ridge Outdoors. https://www.blueridgeoutdoors.com/go-outside/weather-woes/.

[124] Lohr, R. 2019. "Revolutionary snow storage system at Craftsbury Outdoor Center." Revolutionary Snow Storage System at Craftsbury Outdoor Center — Cross Country Skiing (xcskiresorts.com)

[125] Kinney, J. 2015. "Weather woes: Can ski resorts Adapt to Climate Change?"

[126] Seven Spring Mountain Resort. Hiking and Mountain Biking. https://www.7springs.com/summer/hiking-mountain-biking/

[127] Blue Mountain Resort. PA's Largest Downhill Mountain Bike Park. https://www.skibluemt.com/outdoor/mountain-biking/

riding, horseback riding, backcountry hiking, rope courses, tennis, disc golf, archery, yoga, and spa treatments.[128,129,130]

Figure 49. A cyclist mountain biking at Blue Knob State Park[131]

Addressing the Impacts of a Changing Climate on Built Infrastructure

Impacts

Built infrastructure will be significantly impacted by flooding related to sea level rise, tropical and extra-tropical cyclones, and other heavy precipitation events. Impacts will be intense but localized. Individually and acting as concurrent forces (i.e., storm surges) these events could cause severe damage to infrastructure and result in substantial cascading impacts. Vulnerabilities identified in the 2021 Impacts Assessment that could harm built infrastructure include:

- Increased disruption and damage, especially from direct flooding in the Southwestern region, to:
  - Local electricity infrastructure
  - Homes, buildings, and facilities in flood zones
  - Fuel delivery systems (e.g., pipelines including those underground)
  - Transportation infrastructure (e.g., bridges, roads, railways, culverts)
  - Urban stormwater and wastewater management systems

---

[128] Kinney, J. 2015. "Weather woes: Can ski resorts Adapt to Climate Change?" Blue Ridge Outdoors. https://www.blueridgeoutdoors.com/go-outside/weather-woes/.

[129] Unions of Concerned Scientists. 2008. Climate Change in Pennsylvania: Chapter 5 Impacts on Winter Recreation. https://www.nrc.gov/docs/ML0913/ML091390883.pdf.

[130] U.S. Forest Service Office of Communication. 2014. "U.S. Forest Service Finalizes Policy to Promote Year-Round Recreation on Ski Areas." https://www.usda.gov/media/press-releases/2014/04/15/us-forest-service-finalizes-policy-promote-year-round-recreation

[131] Laurel Highlands Bicycling Club. Blue Knob State Park. https://lhorba.org/blue-knob-state-park/.

- Higher risks of cascading impacts from infrastructure service disruptions, including:
  - Temporary halt or reduction in delivery of fuel products (e.g., natural gas, petroleum)
  - Overflow of stormwater and water systems which could be detrimental to water quality, and could cause severe roadway flooding and water infiltration into buildings
  - Extended blackouts
- Increased flood risk to infrastructure in Southeastern Pennsylvania from flooding related to sea level rise and coastal storms with especially significant impacts to:
  - Homes in certain parts of the Philadelphia region
  - Philadelphia International Airport

Key Actors

- **Department of Transportation (PennDOT):** PennDOT could evaluate flooding risks along state roads and work to improve at risk assets and corridors.
- **Pennsylvania Emergency Management Agency**: PEMA could help in coordinating and planning for extreme event responses.
- **DCED**: DCED could help incentivize flood-proof development through its funding, housing and development, and local government programs.
- **PENNVEST:** PENNVEST could include flooding risks considerations in its investments.
- **Public Utility Commission**: The PUC should evaluate flooding risks to infrastructure networks and take appropriate steps to ensure the resilience of networks.
- **State legislature:** The Commonwealth's legislature can increase funding for infrastructure projects aimed at reducing flooding.
- **Municipalities:** Local governments can take action to reduce flood risks through land use policies. Public works departments can specifically focus on updating stormwater and wastewater management systems.
- **Energy utilities and companies:** Utilities and companies should evaluate how flooding could impact their assets, adopt plans to adapt their systems, and ultimately reduce or eliminate risks to vulnerable assets.

Adaptation Strategy Pathway

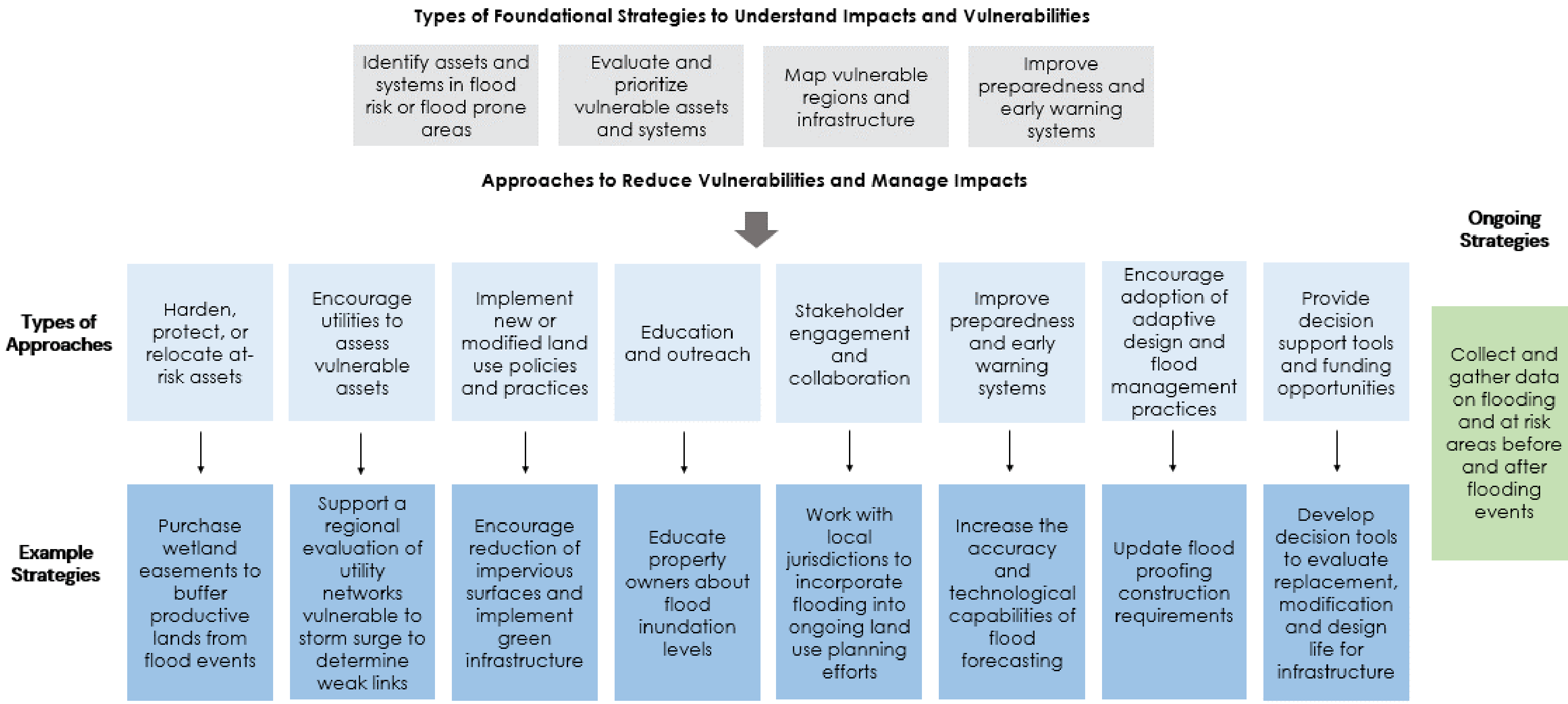
To adapt infrastructure to the impacts of flooding in a changing climate, the Commonwealth must begin by elucidating the highest risk assets and systems. With this information, stakeholders can take steps to update infrastructure assets and build resilience into infrastructure systems.

To address impacts, the Commonwealth can pursue a variety of strategies that engage a wide breadth of stakeholders. These actions range from improving land use policies, developing tools for private sector actors, changing design and engineering practices, and conducting large scale infrastructure improvement projects. Figure 50 outlines the types of strategies that can be deployed to adapt infrastructure assets and systems to the impacts of flooding in a changing climate.

Reducing and adapting to the impacts of flooding in a changing climate will require a multi-sectoral approach throughout the Commonwealth. State agencies (e.g., PennDOT, PEMA), local jurisdictions, utilities, and the construction, design, and engineering sectors will be involved in adaptation. While PennDOT and utilities might focus on building the resilience of their own infrastructure system network, local jurisdictions may use their zoning powers to reduce infrastructure at-risk of being flooded. Each actor has many opportunities to support the Commonwealth's infrastructure adaptation.

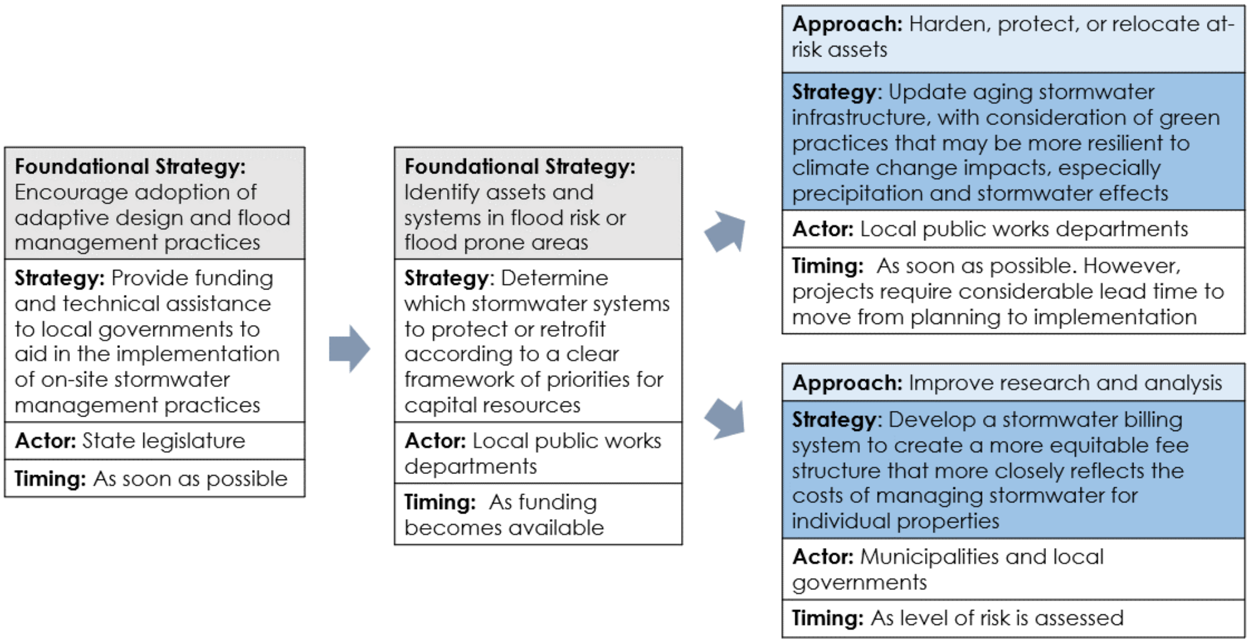
Coordination and engagement are critical as stakeholders work to increase infrastructure's resilience to flooding. Many of these strategies can be taken in conjunction to create a unified approach and increase efforts across the state. Figure 51 outlines an example sequence of four strategies led by state agencies, the legislature, and municipal public works departments to address flooding impacts to stormwater management systems.

Figure 50. Adaptation strategy pathway to reduce impacts of flooding on built infrastructure



This diagram shows the primary types of strategies but does not capture the full universe of possible strategies that could be deployed.

Figure 51. Example set of strategies to be pursued to reduce stormwater infrastructure's vulnerabilities to flooding in a changing climate in the Commonwealth



Some state actors have already begun to pursue actions described in this section. Already, Pennsylvania has many strategic and coordinated efforts to address flooding including the State Planning Board flood hazard mitigation work and PennDOT's climate adaptation efforts.[132,133]

State agencies are also working to provide funding and build capacity at the local level. For example, PEMA administers the Federal Emergency Management Agency's Building Resilient Infrastructure and Communities (BRIC) grant program, which provides funding for local governments to build resilient infrastructure.[135] At the local level, cities, public works departments, and utilities are also acting. For example, the Wyoming Valley Sanitary Authority

In December 2020, the Governor directed the State Planning Board to create recommendations and highlight best practices for addressing flooding.[134] The State Planning Board will focus these efforts on opportunities related to land use, planning, zoning, and storm water management. These recommendations and best practices guidelines will be aimed at helping communities reduce the incidence and impact of flash flooding.

[132] Governor's Office. 2020. "Gov. Wolf Announces Plan to Address Flooding Caused by Climate Change." https://www.governor.pa.gov/newsroom/gov-wolf-announces-plan-to-address-flooding-caused-by-climate-change/

[133] PennDOT. 2019. Extreme Weather Vulnerability Study. https://pennshare.maps.arcgis.com/apps/MapSeries/index.html?appid=29bf9f06045f47feb9888193674f8a95

[134] PA Governor's Office. 2020. "Gov. Wolf Announces Plan to Address Flooding Caused by Climate Change." https://www.governor.pa.gov/newsroom/gov-wolf-announces-plan-to-address-flooding-caused-by-climate-change/?fbclid=IwAR2ZvTFl1cGBPWIUxsZ3ZPxFT6pYaDd4QaVkt5IeVw9QrEI341fAqALyKVA

[135] PEMA. 2020. Building Resilient Infrastructure and Communities (BRIC). https://www.pema.pa.gov/Grants/BRIC/Pages/default.aspx

introduced a stormwater impact fee that funds the Authority's Regional Stormwater Management Program to reduce runoff and pollutants.[136]

Appendix C provides more strategies related to this priority area.

Costs and Benefits

Infrastructure upgrades and improvements typically carry high up-front costs, but some strategies, such as identifying and evaluating assets and infrastructure networks, do not. Generally, strategies in this area are labor intensive because they require research, planning, and implementation.

Although adaptation strategies may have high up-front costs, the Commonwealth will achieve significant economic and health benefits long term by improving the resilience of its infrastructure. Construction and infrastructure improvements will create jobs. Increasing resilience to flooding will also reduce downstream economic effects during storms and flooding events (e.g., road delays that disrupt shipping and travel, blackouts that cause business closures). Mitigation investments are also highly effective in reducing future costs. For example, for every $1 invested by the public sector in disaster mitigation, $6 is saved in recovery costs.[137]

Adapting infrastructure to increased flooding will also reap health benefits. Mitigating damages and disruptions to infrastructure networks will reduce accidents. Updating stormwater and wastewater management systems will also hinder any dangers to water quality. Finally, improving building designs to be flood-proof or flood-ready will lower the likelihood that mold develops in buildings and homes after a flooding event. Overall, improving infrastructure to reduce the impacts of a changing climate will result in important benefits for the Commonwealth.

CASE STUDY

Reducing Flood Hazards in New York City

Flood risks related to climate change and associated infrastructure impacts differ from location to location. But techniques, challenges, and opportunities learned from plans to reduce a variety of flood risks for cities can be cross-applicable. The Hurricane Sandy Rebuilding Task Force (Task Force) and U.S. Department of Housing (HUD) "Rebuild by Design" competition is one such example.

The Task Force and HUD launched this competition in 2013 to crowd-source innovative design solutions to promote resilience in the areas impacted by Hurricane Sandy.[138] Submissions to the competition were expected to differ widely in scope and scale from building retrofits to large green

[136] Wyoming Valley Sanitary Authority. 2021. Stormwater Fee. https://www.wvsa.org/stormwater-management/pages/stormwater-fee

[137] National Institute of Building Sciences. 2019. "Mitigation Saves: Federal Grants Provide a $6 Benefit for Each $1 Invested." https://cdn.ymaws.com/www.nibs.org/resource/resmgr/reports/mitigation_saves_2019/ms_v3_federalgrants.pdf

[138] U.S. Department of Housing. "Hurricane Sandy Rebuilding Task Force: Rebuild by Design. https://www.hud.gov/sandyrebuilding/rebuildbydesign.

infrastructure projects.[139] Nearly 150 teams of engineers, scientists, planners, and designers submitted ideas. Six winning designs were selected based on factors including quality of design and resilience benefits, and local community engagement. One winning project, "The Big U," was awarded $335 million.[140]

"The Big U" proposed building "10 continuous miles of protection" along the impacted coast in New York City. It envisioned segmenting the coast into sections, with each area identifying specific infrastructure and social community planning goals and implementation plans through a series of meetings between community stakeholders and local government officials, informed by engineering and design experts.[141] One of those sections, the East Coast Resiliency Project (ESCR), is currently underway.

Figure 52. "The Big U" vision [142]

The ESCR City Team is led by the departments of Design and Construction and Parks and Recreation, with the Mayor's Office of Resiliency; partners include the Departments of Transportation, Environmental Protection, City Planning, and NYC Economic Development Corporation. They are supported by Design & Environmental teams and a Construction Team.

An "integrated flood protection system" is planned to reduce flood risk, including floodwalls and flood gates, a raised bulkhead and underground seepage barrier, and elevated parks along the East River. Measures to reduce flood impacts (e.g., elevated planting beds to reduce risk of saltwater intrusion) are also incorporated. Other project components include upgraded pedestrian bridges and park entries, and a new amphitheater along the water, all designed with accessibility in mind.[143]

---

[139] U.S. Department of Housing. "Hurricane Sandy: Rebuilding by Design."

[140] Cho, R. 2015. "Rebuilding After Hurricane Sandy." Columbia University Earth Institute. https://blogs.ei.columbia.edu/2015/01/21/rebuilding-after-hurricane-sandy/

[141] ReBuild by Design. 2020. "8 Years After Sandy: Community- Wide Discussion on the Progress of the BIG U." New York University Institute for Public Knowledge. https://ipk.nyu.edu/events/8-years-after-sandy-community-wide-discussion-on-the-progress-of-the-big-u/

[142] Cho, R. 2015. "Rebuilding After Hurricane Sandy." Columbia University Earth Institute. https://blogs.ei.columbia.edu/2015/01/21/rebuilding-after-hurricane-sandy/

[143] City of New York. 2021. East Side Coastal Resiliency Project. https://www1.nyc.gov/site/escr/about/about.page

These natural elements both boost infrastructure resilience and introduce protections for cities. For example, introducing natural infrastructure could also potentially reduce the risk of power outages and the associated economic and health consequences.

Addressing the Impacts of Landslides on Built Infrastructure

Impacts

Landslides may significantly impact the Commonwealth's built infrastructure by causing delays and damage to transportation and energy infrastructure. Landslides could damage roads and cause severe downstream impacts for industries and communities dependent on vulnerable transportation and energy infrastructure networks. The following vulnerabilities of the built infrastructure were identified in the 2021 Impacts Assessment:

- Closures of state and local roads for long periods of time
- Short-term losses of emergency routes
- Disruption of energy transport infrastructure (e.g., natural gas pipelines, electric transmission lines, electric substations)
- Downstream impacts to dependent industries from disruptions to roadway, shipping, and energy delivery networks
- Short-term closures or disruptions to railroads.

Adaptation Strategy Pathway

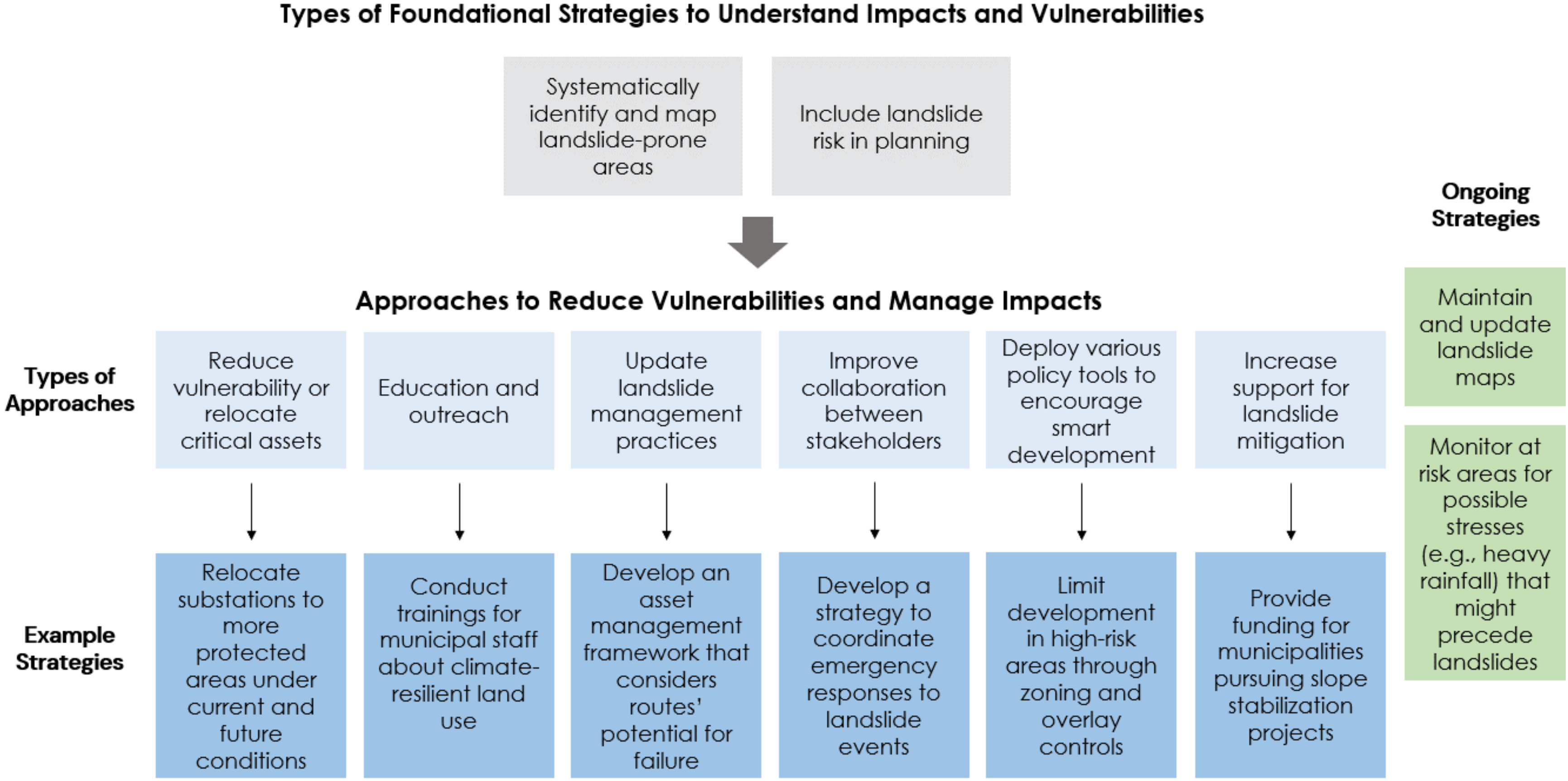
Mitigating the impacts of landslides will require understanding the specific locations exposed and making informed investments to stabilize slopes or otherwise prepare for landslides. DCNR has taken the critical first step of inventorying landslide hazard maps created by the U.S. Geological Survey.[144] Updating maps to reflect current landslide risks and providing them to stakeholders is an important early action. Understanding the level of landslide risk in areas at a high resolution and at specific sites will allow planning and development efforts to better mitigate landslides' potential effects.

To reduce and manage impacts, the Commonwealth can take steps to target critical assets, improve planning and development to be climate change informed, incentivize smart growth and landslide mitigation projects, and improve management practices. These strategies will reduce downstream impacts and improve the resilience of infrastructure networks (i.e., energy and transportation) throughout Pennsylvania.

---

[144] DCNR. USGS Landslide Map Inventory. elibrary.dcnr.pa.gov/GetDocument?docId=1751966&DocName=Hyperlinks_USGSLandslideInventoryMaps_Pa

Figure 53. Adaptation strategy pathway to reduce landslides impact on built infrastructure



This diagram provides an illustrative example of the primary types of strategies but does not capture the full universe of possible strategies.

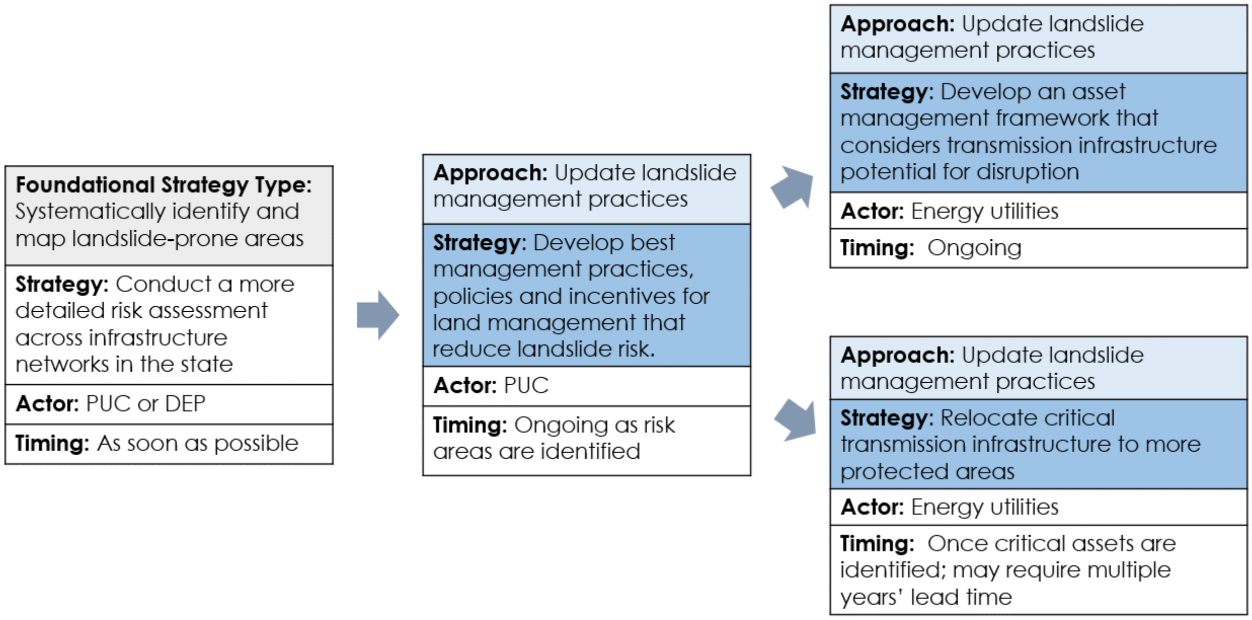
Many stakeholders can contribute to landslide risk mitigation. PennDOT is responsible primarily for reducing impacts to transportation infrastructure networks. Local governments will also play a key role in conducting projects to mitigate landslides in their jurisdictions. Utilities can also work internally to mitigate landslide risks to their assets. Other actors (e.g., legislature, other agencies, universities) can play more peripheral roles by providing support and tools to adapt vulnerable assets and ensure development is climate change- and landslide-risk informed.

Stakeholders must understand the magnitude of impacts that Pennsylvania's infrastructure assets face to be able to prioritize critical assets and vulnerable areas. Figure 54 outlines a sequence of four strategies that could be pursued by state agencies (DEP and PUC) to reduce risks to energy utilities. Appendix C provides more strategies related to this priority area.

Key Actors

- **PennDOT:** PennDOT could evaluate landslide risks along state roads and act to reduce dependencies on at-risk routes.
- **DCNR:** DCNR could support landslide mapping efforts.
- **DCED:** DCED could incentivize development outside landslide hazard zones.
- **Infrastructure Investment Authority (PENNVEST):** PENNVEST could include landslide risk considerations in its investments.
- **Public Utility Commission:** PUC should evaluate risks to energy infrastructure networks and take appropriate steps to ensure the resilience of networks.
- **Pennsylvania Emergency Management Agency:** PEMA could help in coordinating and planning landslide event responses.
- **State legislature:** The Commonwealth's legislature can increase funding for landslide risk mitigation.
- **Municipalities:** Local jurisdictions will be responsible for implementing many actual infrastructure protection projects.
- **Energy utilities and companies:** Utilities and companies should evaluate how landslides could impact their assets and take adequate steps to mitigate those risks.

Figure 54. Example set of strategies to be pursued to reduce energy infrastructure's vulnerabilities to landslides in the Commonwealth.



Costs and Benefits

Adaptation strategies in this priority area that directly address infrastructure risks generally have high up-front costs. For example, infrastructure improvement and slope stabilization projects are expensive. In the case of small landslides affecting only a couple of properties, slope stabilization and repair projects can be prohibitively expensive, with costs exceeding the net value of the properties.[145]

Other strategies, especially those that are foundational, will be less costly. Antecedent steps like mapping, monitoring, and planning will likely be less extensive but require substantial data and expertise. Other less-costly strategies include outreach, updates to management practices, and improvement of collaboration between stakeholders.

Although many actions have high up-front capital costs, the steps can reap massive benefits. Improving the resilience of infrastructure systems to landslides will reduce the potential for infrastructure network disruptions and failures. These disruptions and failures can cause severe downstream impacts that have ripple effects through the Commonwealth's communities and economy. By improving infrastructure resilience to landslides, the Commonwealth can also help mitigate future repair and maintenance costs. For example, one study found that surface-water drainage measures reduced the probability of landslides and the benefits of these measures exceed the costs by a ratio of nearly 3:1.[146] Limiting landslide impacts in landslide-

---

[145] DCNR. "Landslides." https://www.dcnr.pa.gov/Geology/GeologicHazards/Landslides/Pages/default.aspx

[146] Holcombe, E.A., Smith, S., Wright, E., Anderson, M.G. 2012. An integrated approach for evaluating the effectiveness of landslide hazard reduction in vulnerable communities in the Caribbean. *Natural Hazards*, 61(2): 351-385.

prone areas will likely mean that municipalities and state agencies do not have to spend significant portions of their budget repairing damages. Additionally, challenges with long-term road closures from landslides will be reduced. Adapting to landslide impacts will boost the reliability of critical infrastructure in the Commonwealth, and mitigating landslide impacts will boost economic resilience and limit safety challenges (e.g., injuries in car accidents) associated with landslides.

CASE STUDY

Predicting and Mapping Landslides in Allegheny County

In 2018, Allegheny County experienced landslides that caused an estimated $40 million in damage.[147] The landslides also damaged over 130 properties. Extreme rainfall in February 2018 created the conditions that drove the large-scale landslides seen in the county that year.[148] Landslides disrupted infrastructure, and damaged utility pipes and electricity infrastructure.

To address the landslide challenge, the county created a Landslide Task Force. The Task Force aims to provide the necessary resources to help municipalities in the county adapt to landslide hazards. The task force coordinates with county departments (e.g., Emergency Services, Public Works, Budget) and external stakeholders (e.g., Carnegie Mellon, PEMA, National Weather Service, PennDOT, DEP, utilities).[149] Unifying the expertise and resources of these stakeholders, the Task Force works to:

- Create education and communications for municipalities on landslides.
- Provide up-to-date landslide information,
- Understand opportunities related to landslide mitigation grants to help municipalities take advantage of these programs. [150]

The county developed a Landslide map tool that not only identifies sites with recent or historic landslides, but also highlights areas with landslide risks.[151] Areas included in the map might have slope stability challenges that are problematic for infrastructure development. The map aims to provide an initial screen of areas that should be examined in depth with a technical analysis.

The county is also partnering with researchers at Carnegie Mellon University. The interdisciplinary university research team is developing a deep learning model to predict where landslides might occur. The team uses photographs of infrastructure in the county and historical and geological data.[152] If successful, this tool would help to anticipate future landslide threats so that landslide events can be prevented. Additionally, the researchers hope that this the tool can provide data-based indicators that inform local county and municipal policy and budgets.[153]

---

[147] L. Prastien. 2019. "Climate Change Is Causing More Landslides, Machine Learning Can Help Predict Where." Carnegie Mellon University news. https://www.cmu.edu/news/stories/archives/2019/september/climate-change-landslides.html

[148] Allegheny County. 2019. Allegheny County Landslide Portal. https://landslide-portal-alcogis.opendata.arcgis.com/

[149] Allegheny County. 2019. Allegheny County Landslide Portal.

[150] Allegheny County. 2019. Allegheny County Landslide Portal

[151] Allegheny County. 2020. Landslide map tools. https://landslide-portal-alcogis.opendata.arcgis.com/pages/map-tools.

[152] Prastien, L. 2019. "Climate Change Is Causing More Landslides."

[153] Prastien, L. 2019. "Climate Change Is Causing More Landslides."

5 IMPLEMENTING CLIMATE ACTION IN PENNSYLVANIA

A plan is only effective if it used to shape and drive implementation. This section outlines the primary challenges and opportunities to implement the strategies and approaches outlined in the CAP, the principles that will guide implementation efforts, and how implementation practices can ensure outcomes will be beneficial and equitable for all. The section concludes by describing some of the key stakeholders and steps to implement the CAP.

Implementation Challenges and Opportunities

Implementation of broad GHG reduction and climate adaptation measures will undoubtably encounter challenges and create opportunities for the Commonwealth. Although each strategy and pathway has its own unique set of obstacles, several challenges are common to all sectors.

Challenge: Costs

Actions to mitigate the effects of climate change, whether those discussed here or other investments in building a resilient Pennsylvania, may require significant outlays of vital resources. Upfront costs and lack of funding can slow progress and create a significant challenge to implementation. To overcome this challenge, stakeholders and policymakers need to take a full and holistic accounting of costs and benefits throughout the policy or program, including the cost of inaction and future cost savings as a result of proactive climate action. This should include health and equity impacts, storm recovery costs, and all manner of impacts articulated in this plan.

Potential Grant Opportunity: FEMA Building Resilient Infrastructure in Communities

The Building Resilient Infrastructure and Communities (BRIC) program aims to categorically shift the federal focus away from reactive disaster spending and toward proactive, research-supported investment in community resilience. BRIC is designed to fund ambitious pre-disaster hazard mitigation projects, allowing grantees to safeguard their communities from the destruction and disruption of hurricanes and other natural disasters.

The cost-share for FEMA BRIC generally is 75% federal and 25% state and local. BRIC funding presents opportunities to build resilience to hazards or extreme events.

To mitigate costs and impacts on different groups in Pennsylvania, Pennsylvania could effectively invest revenue generated from putting a price on carbon, or apply funds obtained through COVID-19 recovery stimulus or other federal funding. Potential stimulus revenues or new funding sources could help pay for critical programs and actions. Such revenues can be strategically invested in a number of ways, including in clean energy and energy efficiency programs, GHG abatement and jobs, and supporting vulnerable communities and environmental justice communities. Additionally, the costs of solar and wind technologies have declined rapidly in the last decade, and other clean energy technologies like EVs and battery storage may do the same, thereby reducing the financial burden of implementing GHG reduction strategies. Improving the efficiency or reducing the costs of these technologies is also a potential business opportunity for local manufacturers.

Challenge: Political will and resistance to change

Implementing climate change mitigation and adaptation strategies will create changes to the ways that Pennsylvanians live, work, and get around. Resistance to change can manifest itself as lack of political will, causing delays to new legislation and hesitancy in rolling out new policies and programs. Education and outreach are key to helping Pennsylvanians understand the planned changes and program goals. Efforts should aim to both explain climate change and outline the many co-benefits of taking action, including job creation, improved air and water quality, and the many health benefits that can be enjoyed with improved environmental quality. Careful program design can help alleviate concerns, focus efforts on specific priorities, use funding effectively and efficiently, and create equitable and fair policies to achieve greater buy-in from diverse stakeholders.

Opportunity: Increase jobs and expand businesses

As new technologies and policies are implemented, new opportunities for business and job growth will emerge. Clean energy technologies have already shown their potential to create new jobs and businesses as wind turbine service technicians and solar photovoltaic installers are two of the top three fastest growing jobs over the past 10 years.[154] Future climate mitigation and adaptation technologies could offer similar job and business growth potential. Pennsylvania already supports the state's work in energy employment transitions through DEP's workforce development programs[155] and can continue to grow its commitment to workers through the implementation of RGGI dollars.

Opportunity: Build resiliency

As the Commonwealth prepares to build new infrastructure like bridges, buildings, and roads, it can leverage new technology, design, and planning to ensure its infrastructure and communities are more resilient to climate change. Industries and local governments can adopt plans to adapt their systems and infrastructure to ultimately reduce or eliminate risks to their vulnerable assets. This will be particularly important in the energy sector, as trends toward electrification, distributed energy resources, and renewable energy increase the imperative and complexity associated with electric grid reliability. Program implementation can broaden resiliency by incorporating and emphasizing risks and hazards and incorporating adaptative measures. This work can be supported by a variety of funding sources such as the FEMA BRIC program that aim to make both communities and infrastructure more resilient.

Opportunity: Increase equity

Often those that are most affected by climate change live in communities with the least capacity to adapt to and prepare for climate impacts because of compounding inequities. Additionally,

---

[154] Bureau of Labor and Statistics. 2021. "Fastest Growing Occupation." Accessed April 5, 2021. https://www.bls.gov/ooh/fastest-growing.htm.

[155] Pennsylvania DEP. 2021. Workforce Development. Accessed April 12, 2021. https://www.dep.pa.gov/Business/Energy/OfficeofPollutionPrevention/EnergyEfficiency_Environment_and_EconomicsInitiative/Pages/Workforce-Development.aspx

cost burdens associated with energy-inefficient housing or access to affordable transportation impact low-income Pennsylvanians. Through the implementation of this plan, extra attention should be given to design future projects and programs to address these inequities. Improving equity can overlap with job growth opportunities. Job training and advancement programs should be focused on low-income and marginalized individuals so that they can participate in the clean energy economy.

Opportunity: Increase environmental and health benefits

With the reduced combustion of fossil fuels, the Commonwealth would see a sharp decrease in air and water pollutants, improving the health of Pennsylvanians. Improved air quality will reduce air pollutants such as SO_x, NO_x, mercury, PM, and ozone, which are major causes to a variety of harmful health impacts including asthma, heart attacks, cancer, and shortened lives. Air pollutants present a higher risk to children, older adults, and people with lower incomes.[156] Pennsylvanians should also see cleaner water through implementation, through reduced acid mine drainage, decreased thermal pollution near major power plants, and fewer instances of coal ash water contamination.

Opportunity: Optimize land use

The strategies outlined in this CAP provide opportunities to optimize land uses (e.g., suitable locations for solar, public transit-oriented development). Optimal land use also presents a prime opportunity to implement both GHG reduction and climate adaptation strategies in concert. Successfully integrated strategy implementation may result in maximizing co-benefits.

Implementation Principles

To effectively implement the CAP and the strategies proposed in it, strategy implementation will be guided by the following principles:

- Consider the needs of vulnerable communities and the effects of actions on equity, access, and inclusion.
- Enhance collaboration between government and stakeholders.
- Conduct monitoring and evaluation (M&E) assessments of strategies.

These principles and methods to integrate them into implementation are described below.

Equitable and Beneficial Implementation

In addition to following the implementation principles described above, DEP favors an implementation approach that is designed to equitably improve the lives of Pennsylvanians. Both the benefits and costs of implementing the CAP should be equitably distributed to maximally improve the lives of everyone, and to avoid unfairly burdening certain communities

---

[156] American Lung Association. Lung Health Policy Brief. Accessed April 12, 2021. https://www.lung.org/getmedia/e310efd8-b189-4411-b3a3-7db31dc54baa/clean-energy-policy-brief_.pdf.

or populations or disproportionately favoring others. To begin considering potential equity effects, DEP applied an equity criterion to the processes of evaluating the potential GHG reduction strategies and adaptation strategies. The modeling of the selected strategies included developing outputs for the potential social and economic effects, such as improved air quality and public safety, job creation, and increased income. But to maximize those benefits and minimize those costs in an equitable manner, the implementation of the selected strategies must be carefully designed.

Climate change will not affect all Pennsylvanians equally. Some may be more vulnerable to impacts due to their location, income, housing, or other factors. For example, certain populations may have greater physical exposure to risks (e.g., construction workers may be more exposed to heat waves) or limitations to their ability to manage consequences if they occur (e.g., income or wealth may impact ability to pay for air conditioning).

Disproportionate impacts are often not random. Consequences of historical discriminatory practices, such as redlining and disinvestment, may also manifest as inequities today. For example, individuals living in deteriorating housing may be more exposed to heat stress.[157] As Pennsylvania works to reduce its climate risks, care needs to be taken that these inequitable impacts are addressed, and that adaptation efforts do not inadvertently exacerbate existing inequities.

Some of the primary ways to design for equitable and beneficial outcomes are to develop equity indicators, identify areas or communities with low equity outcomes, assess the causes of inequity and the needs of different communities, and then develop implementation methods that reduce the causes of inequity and match beneficial outcomes with communities that lack those benefits the most. To do this requires careful analysis, public engagement, and careful M&E to make corrections as needed. Additional funding sources, too, can help ensure that implementing the strategies outlined in the CAP address the needs of different communities. Designing implementation methods in this way helps to protect and improve public health, safety, and welfare; mitigates adverse impacts on traditionally marginalized communities; helps to address the legacy impacts of past discrimination, racism, and environmental injustice; and ensures that all Pennsylvanians benefit from a cleaner, greener environment.

Creating jobs and economic opportunity

From 2017 to 2019, clean energy jobs grew by 8.7%, which was more than four times the average job growth rate. In 2019, there were over 97,000 clean energy jobs statewide. Most job growth occurred in the solar and wind energy industries and in construction, but the majority of clean energy jobs are in the energy efficiency industry. All clean energy generation technologies

---

[157] K. Maxwell, S. Julius, A. Grambsch, A. Kosmal, L. Larson, and N. Sonti. 2018. "Built Environment, Urban Systems, and Cities." In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, pp. 438–478. doi: 10.7930/NCA4.2018.CH11.

experienced growth from 2017 to 2019 with the exception of nuclear power.[158] Though some clean energy jobs have been lost since the pandemic arrived, the industry is expected to continue to grow as the economy recovers.

Clean energy jobs pay more on average compared to the occupation's statewide median wage. About two-thirds of clean energy jobs paid a premium compared to the statewide median across energy technology sectors and experience levels, and nearly 87% of entry-level jobs paid more than the median wage. Additionally, the clean energy industry employs a diverse labor force. Hispanic/Latinx, American Indians, Asian Americans, African Americans, and veterans were all employed at greater rates than statewide demographic averages.[159]

Taken together, these factors—high job growth, above average pay, more diverse labor demographics—all indicate that the transition to a clean energy economy can help improve equitable and beneficial outcomes in Pennsylvania. Looking to the future, A 2021 study estimates that Pennsylvania can create 243,000 net jobs annually from 2021-2030 through clean energy investments. 162,000 jobs would be clean energy jobs, and 81,000 jobs would be in supporting industries such as in public infrastructure, manufacturing, land restoration, and agriculture. To achieve these numbers, the study estimates that an average annual investment of $31 billion would be needed (about 3% of the Commonwealth's GSP). Some of that investment would also come from the federal government, which has recently pledged to invest $2 trillion in clean energy efforts.[160]

This job growth could assist the "just transition"—a shift from a fossil-based economy to a clean energy economy. To do so, it will be important for the industry and the State to educate and train workers to prepare them for clean energy careers, because a lack of training or experience was the main reason that clean energy employers found finding qualified applicants difficult.[161] Retraining workers in natural gas, coal, and similar industries for clean energy careers would ease their burden and may help overcome a fear of change or a lack of political will. Targeted and adequate funding, too, will be necessary to ensure economic and employment opportunities are maximized.

---

[158] DEP. 2020. 2020 Pennsylvania Clean Energy Employment Report. https://www.dep.pa.gov/Business/Energy/OfficeofPollutionPrevention/EnergyEfficiency_Environment_and_EconomicsInitiative/Pages/Workforce-Development.aspx.

[159] DEP. 2020. 2020 Pennsylvania Clean Energy Employment Report.

[160] StateImpact Pennsylvania. 2021. "Report: Pennsylvania stands to gain 243,000 jobs a year from clean energy investment." https://stateimpact.npr.org/pennsylvania/2021/01/29/report-pennsylvania-stands-to-gain-243000-jobs-a-year-from-clean-energy-investment/.

[161] DEP. 2020. 2020 Pennsylvania Clean Energy Employment Report. https://www.dep.pa.gov/Business/Energy/OfficeofPollutionPrevention/EnergyEfficiency_Environment_and_EconomicsInitiative/Pages/Workforce-Development.aspx.

Addressing health and equity

Human health is influenced by the local climate and environment. Pollutants such as such as SO_x, NO_x, mercury, and others are emitted when burning fossil fuels and can cause negative health effects such as asthma, cardiac arrest, cancer, and premature death. Reducing GHG emissions reduces emissions of these pollutants and helps to improve the quality of air and water, thereby reducing the associated health hazards and improving public health. Because the risk of experiencing negative health effects caused by pollution are higher for children, older adults, and people with lower incomes, reducing pollution and improving health outcomes increases equitable outcomes.

Historically, not all people or communities have benefited equally from the development of public, industrial, and commercial infrastructure, goods, and services. In fact, low-income and minority communities have often been negatively affected and experience a disproportionately large amount of reduced environmental quality and increased health hazards, and a disproportionately small amount of economic, environmental, and social benefits. Such disproportionate outcomes may not be intentional in some cases, but because these communities lack resources and representation, and because equity has not been integrated into past planning and implementation efforts, inequitable outcomes do occur. However, planners and implementers have increasingly become aware of this issue and are designing policies and programs—such as this CAP—that strive to achieve more equitable outcomes for all.

GHG reduction strategies have the potential to advance health and equity by improving air quality in disproportionately impacted communities, reducing energy bills in low-income households through building weatherization and strategic electrification, increasing transit options in areas with low accessibility, and much more. Similarly, adaptation pathways can improve equity by providing vulnerable communities with shelter from extreme temperatures and reducing the risk of health hazards from extreme weather events and vector-borne diseases.

Key Stakeholders and Collaboration

A broad range of stakeholders, including government actors, industry and business leaders, nonprofit organizations, and Pennsylvania citizens must work together on climate and energy policies and programs that support the economy, public health, and the environment, leading to a low-carbon and more resilient Commonwealth.

Collaboration with other agencies and organizations allows for the pooling of resources and information to achieve more than agencies or organizations could accomplish individually. To succeed in implementing climate mitigation and resiliency measures, stakeholders with overlapping work will need to work together despite varying areas of expertise and differing views on certain subjects. Coordination among stakeholders should begin at the very start of the planning stages of any new policy or program.

Pennsylvania citizens: Citizens of the Commonwealth need to be part of the conversation on climate and program and policy makers should seek many methods to gather feedback, including open houses and topic specific forums on proposals. Impacts on Pennsylvanians will be significant, and they can provide feedback on a variety of issues, but their perspective on how changes impact their communities, homes and work are especially crucial. Specific outreach to underrepresented populations, and marginalized communities needs to be considered to ensure that changes help reduce social and racial inequities. Work in underrepresented populations can be enabled through community leaders and grassroots organizations that are experienced and rooted in these communities.

Business and industry: Business and industry leaders offer a critical perspective on progress on climate. Mitigating and adapting to climate change will create many opportunities for businesses, including the possibility for new jobs and growth industries. Change may be difficult for some, and new opportunities may not be in the same industry or may require businesses to make significant changes or investments. Policies and program designers should work with businesses to ease transitions and listen to them on a variety of issues. For example, business leaders have experience with how to develop supply chains and understand methods for effective job training.

State government agencies: Collaborations between state agencies should be strongly encouraged to ensure programs and policies are effectively designed and implemented. Perspectives on implementation that differ from the lead agency's approach should be encouraged such that new policies and programs have broad acceptance and are coordinated between many agencies.

Pennsylvania Public Utilities Commission: As new laws are made by Pennsylvania's legislature, the PA PUC will be charged with implementing them fairly and ensuring that utility company operations (water, energy, telecommunications, and transportation) run smoothly. The PA PUC oversight is critical to ensuring that utilities incorporate climate resiliency into their infrastructure planning and operations.

Utilities: In addition to their significant impact on energy, utility companies play an outsized role in the infrastructure, resiliency, and connectivity of the communities they serve. Electric and gas utilities will serve as program implementer for a variety of energy efficiency and resiliency measures and provide connectivity to new technologies and solutions. Telecommunications and water utilities have critical roles in recovery from storms and other hazards. Partnership, cooperation and cocreation of programs will be critical to successful implementation.

Local government: Many local governments are already working to plan and implement climate mitigation and adaptation strategies for their communities and are supported by state programs, partnerships, and resources. Continued partnership and program expansions will help ensure that local perspectives are incorporated into state work and that local implementers have sources of support in the state.

State legislature: The Commonwealth's legislature can greatly influence how climate mitigation and resiliency strategies are implemented. They can pass legislation requiring reduced GHG emissions from various sectors, incorporating new policies and laws and changing funding for state-run programs.

Federal government: Although the Commonwealth can implement many programs and policies, the Federal government through its programs, funding, rules, and laws has outsized influence over all national emissions sectors. Federal funding and legislation can reduce emissions rapidly and expand climate resilience strategies.

Strategy Monitoring and Evaluation

Monitoring and Evaluation (M&E) is a framework for and a core aspect of effective implementation. M&E is used to track and assess the performance of strategies with the goal of improving current and future performance. Monitoring entails periodically or continuously tracking the outcomes or impacts of a program. Consistent monitoring over the course of strategy implementation (rather than only at the end) allows implementing actors to identify and correct inefficiencies, errors, and other unwanted impacts as they arise. Monitoring can be qualitative (e.g., surveys, interviews) and quantitative (e.g., tracking metrics like the amount of emissions reduced annually). Sometimes, monitoring can identify obvious errors that can be corrected immediately, but sometimes, data must be evaluated for a full understanding of the results.

Evaluation entails an objective and thorough analysis of the monitoring results to determine the effectiveness and efficiency of the strategy in achieving intended results. Evaluation experts determine what is working well and what is not working, so that underperforming aspects can be corrected and performing aspects can be maximized, thereby improving the overall impact of the strategy over time. Evaluation exercises are conducted by experts who often apply a framework or performance criteria to assess the monitoring data. The framework or criteria must be developed before implementation and should reflect the priorities and goals of the strategies.

Although M&E requires additional resources, the potential cost savings and long-term improvements in performance typically offset resource costs. Evaluation findings can be used to promote projects or policies, raise awareness, attract investment, and provide accountability and transparency. The lessons learned in strategy evaluations can be applied to similar and future efforts to maximize their effect.

APPENDIX A. KEY TERMS

Glossary

Adaptation—The process of adjusting to new or changing climate conditions to reduce or avoid negative impacts to valued assets and take advantage of emerging opportunities.

Adaptation strategy pathways—Example categories and sequencing of adaptation strategies intended to provide ways the Commonwealth can adaptively manage climate change impacts over time.

Adaptive management—An iterative risk management approach. As conditions change, adaptive management suggests using adaptation actions that address current risks and preparing for variable future changes. This approach provides flexibility to assess continuously changing risks and undertake appropriate actions to mitigate those risks.

Cost per ton of CO_2 reduced—Represents the net present value of the action used to reduce CO_2 divided by the total cumulative CO_2 reduced over the study period. This metric represents the per-unit cost of reducing CO_2. Negative cost-per-ton represents net cost savings.

Disposable personal income—Represents the total after-tax income, of individuals, available for spending or saving in 2019 dollars.

EJ areas—Environmental justice census tracts, where 20% or more individuals live in poverty, and/or 30% or more of the population is minority.[162]

Energy consumed—End-use consumption of energy fuels and electricity in Pennsylvania's residential, commercial, industrial, and transport sectors.

Energy generated—Grid-connected electricity generating units located in Pennsylvania or other energy generation sources located in Pennsylvania facilities.

Exposed areas—Geographic areas projected to be affected by climate change based on climate change projections.

Gross state product (GSP)—Measure of a state's output in 2019 dollars. This metric represents the sum of value added for all industries in the state and is the counterpart of the Nation's gross domestic product (GDP).

Greenhouse gases (GHG)—Gases that trap heat in the atmosphere, contributing to global warming and climate change. Common GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_20), and fluorinated gases.

GHG reductions—Reducing the emissions of heat-trapping greenhouse gases into the atmosphere.

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

Impacts—refers to the effects of a climate hazard, e.g., potential impacts of warmer temperatures include health risks on hot days.

Job-year—One year of work for one person. For example, a new construction job that lasts five years is five job-years.

Net present value (NPV)—The difference between expenditures (cash outflows or costs) and savings (cash inflows or benefits). These expenditures and savings are discounted to present values to represent the time value of money (the precept that money available now is worth more than an identical sum in the future). NPV is only one metric used to assess the economic effects of an action. It does not include externality costs, such as those of GHGs or other emissions. A positive NPV indicates that cash inflows are greater than costs, whereas a negative NPV indicates the opposite. A negative NPV does not necessarily indicate that a strategy or action is not cost-effective, as there are other metrics that should be used to evaluate cost-effectiveness of an action (e.g., cost per ton of CO_2 reduced, or macroeconomic benefits). A discount rate of 1.75% was used in this analysis, as representative of a societal policy perspective.

Overburdened populations—"Minority, low-income, tribal, or indigenous populations or geographic locations … that potentially experience disproportionate environmental harms and risks."[163] Environmental justice areas are used in this assessment as a proxy for locations where populations are already overburdened by hazards and other structural disadvantages.

Resilience—The capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from disturbances, while retaining the basic functions of the system.

Risk—The chance a climate hazard with cause harm. Risk is a function of the likelihood of an adverse climate impact occurring and the severity of its consequences (e.g., Risk = Likelihood x Consequence).

Vulnerable populations—Populations more likely to experience adverse impacts from exposure to climate hazards because of demographics factors (e.g., race, gender), socio-economic status, and life- or livelihood-sustaining needs (e.g., dependence on electricity for critical medical care).

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

Abbreviations and Acronyms

ACEEE	American Council for an Energy-Efficient Economy
AEC	Alternative Energy Credits
AEO	Annual Energy Outlook
AEPS	Alternative Energy Portfolio Standard
AFIG	Alternative Fuels Incentive Grant
AFV	Alternative Fuel Vehicle
AIM	American Innovation and Manufacturing Act
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAU	Business as usual
BMP	Best management practices
BTU	British thermal units
BRIC	Building Resilient Infrastructure and Communities
C-PACE	Commercial Property Assessed Clean Energy
CAFE	Corporate Average Fuel Economy Standard
CAP	Climate action plan
CCAC	Climate Change Advisory Committee
CCUS	Carbon capture, utilization, and storage
CCVI	Climate change vulnerability index
CGE	Computable general equilibrium
CHP	Combined heat and power
CIP	Capital Improvement(s) Plan or Program
DAC	Direct Air Capture
DCNR	Department of Conservation and Natural Resources
DEI	Diversity, Equity, and Inclusion
DEP	Department of Environmental Protection
DER	Distributed energy resources
DOE	Department of Energy
DOH	Department of Health
DOT	Department of Transportation
DPI	Disposable personal income
DSM	Demand side management
EDC	Electric distribution companies
EERS	Energy Efficiency Resource Standard
EIA	Energy Information Administration
EJ	Environmental justice
EO	Executive order
EPA	Environmental Protection Agency

ESCR	East Coast Resiliency Project
EV	Electric vehicle
FAST	Fixing America's Surface Transportation
FEAT	Farm Energy Audit Tool
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FIA	Forest Inventory and Analysis
FLIGHT	Facility Level Information on Greenhouse Gases Tool
GDP	Gross domestic product
GHG	Greenhouse gas
GSP	Gross state product
HFC	Hydrofluorocarbon
HSPF	Heating Seasonal Performance Factor
HUD	U.S. Department of Housing
HVAC	Heating, ventilation, and air conditioning
ICE	Internal combustion engine
IEA	International Energy Agency
IECC	International Energy Conservation Code
IgCC	International Green Construction Code
IPM	Integrated Planning Model
LCFS	Low Carbon Fuels Standard
LIHEAP	Low-Income Home Energy Assistance Program
LIURP	Low-Income Usage Reduction Program
LMI	Low- to moderate-income
LMOP	Landfill Methane Outreach Program
LPG	Liquefied petroleum gas
LULUCF	Land use, land-use change, and forestry
M&E	Monitoring and evaluation
MATS	Mercury Air Toxic Standards
MHD	Medium- and heavy-duty
MOU	Memorandum of understanding
MOVES	Motor Vehicle Emission Simulator
MPO	Metropolitan planning organizations
MT	Metric ton
NAECA	National Appliance Energy Conservation Act
NPV	Net present value
NRCS	Natural Resources Conservation Service
NREL	National Renewable Energy Laboratory
ODS	Ozone-depleting substance

OEJ	Office of Environmental Justice
O&M	Operations and maintenance
OOS	Office of Sustainability
OPS	Office of Pipeline Safety
PA	Pennsylvania
PennDOT	Pennsylvania Department of Transportation
PNHP	Pennsylvania Natural Heritage Program
PNNL	Pacific Northwest National Laboratory
PUC	Public Utility Commission
PV	Photovoltaic
R&C	Residential and Commercial
RGGI	Regional Greenhouse Gas Initiative
RNG	Renewable natural gas
SCC	Social cost of carbon
SEDS	State Energy Data System
SIT	State Inventory Tool
SLR	Subsequent License Renewal
SREC	Solar renewable energy credits
SWE	Statewide Evaluator
UHI	Urban Heat Island
USDA	U.S. Department of Agriculture
VMT	Vehicle miles traveled
VOC	Volatile organic compounds
WAP	Weatherization Assistance Program
WPC	Western Pennsylvania Conservancy
WRRFS	Water resource recovery facilities
ZEC	Zero Emission Credit
ZEV	Zero Emission Vehicle

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 and the Energy Assessment Report. The exceptions to this methodology and data sources are noted below. The primary methodological steps undertaken were as follows:

- 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 provides an overview of these data sources in more detail.
- 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 regulations on oil and gas emission controls and the Aim Act HFC phaseout, were incorporated as described below.
- 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).
- 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. Historical data from the SIT were used up through 2017, which was chosen to match the latest available SIT data in DEP's most recent GHG inventory. 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 before 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 Pennsylvania's seven largest electric distribution companies (EDCs) to reduce energy use in their service territory.
- **Alternative Energy Portfolio Standard.** AEPS sets targets for the amount of electricity supplied by PA's EDCs that must come from renewable and alternative sources.
- **Regional Greenhouse Gas Initiative.** By joining RGGI, Pennsylvania is obligated to reduce their GHG emissions in coordination with other member states.
- **HFC Phaseout.** Pennsylvania will phase out HFCs in accordance with the American Innovation and Manufacturing (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 Kigali Amendment phaseout (which provides a schedule of HFC phaseout that could align with the recently passed AIM Act that is yet to be written into 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 from 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).[164] 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, and a listing of wastewater sites in Pennsylvania,[165] 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

---

[164] 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

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

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; however, our model currently holds the 2030 cap in place for the remainder of the time series. Data regarding the stringency of the cap beyond 2030 was not available at the time the IPM modeling was performed.

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.

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.

Land Use, Land-Use Change, and Forestry (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"). See also below on GHG emissions for electricity generation.
- Reductions in GHG emissions as a result of changes in both electricity consumption and the generation mix are accounted for in the electricity generation sectors. GHG emissions from electricity generation are modeled in a two-step process:
  - Estimate changes in electric load as a result of all strategies that impact 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. 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).

Buildings Sector

A. 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, encourage or 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,[166] the analysis team assumed an International Energy Conservation Code (IECC) 2015 base code and then implemented

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

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.[167] 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.[168] New home projections were provided by Pacific Northwest National Laboratory.[169] 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 should be applied before 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.

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

---

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

[168] 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.

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

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[170] and PNNL's Cost-Effectiveness Analysis of the Residential Provisions of the 2015 IECC for Pennsylvania.[171]

Assumptions and data: For Residential: The Total Housing Units for the State of Pennsylvania and throughout the US was take from US Census data.[172] Data on Pennsylvania homeownership was taken from St. Louis FED.[173] A value for U.S. home owners reporting retrofit projects was taken from Harvard's work on Improving America's Homes.[174] 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. An 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 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.

B. 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 in the existing framework of or a modified framework of Act 129 and other program (e.g., increasing savings targets and removing spending caps).

For Act 129, this may include increasing the low- to moderate-income (LMI) share of spending and reforming cost-effectiveness tests to support more LMI focus, in coordination with the Low Income Usage Reduction Program (LIURP), and adding climate mitigation and resilience

---

[170] PNNL. 2014 https://www.energycodes.gov/sites/default/files/documents/Cost-effectiveness_of_ASHRAE_Standard_90-1-2013-Pennsylvania.pdf

[171] PNNL. 2015 https://www.energycodes.gov/sites/default/files/documents/PennsylvaniaResidentialCostEffectiveness_2015.pdf

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

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

[174] 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

benefits to cost effectiveness tests. To enhance Act 129 effectiveness and increase savings, incentives and education should also leverage programs like the federally-funded 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%). Maximum achievable takes into account market barriers, and program savings realization rates. 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 in Philadelphia[175], and PNNL analysis[176] of building performance potential.

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 Strategy A.

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).

---

[175] City of Philadelphia. Philadelphia Building Energy Benchmarking 2019 Report. Accessed April 8, 2021. https://www.phila.gov/media/20191210091804/2019-Municipal-Energy-Benchmarking-Report.pdf

[176] Pacific Northwest National Laboratories. Improving Commercial Building Operations through Building Re-tuning™: Meta-Analysis. Accessed April 8, 2021. https://buildingretuning.pnnl.gov/documents/PNNL-SA-156277_Re-tuningMeta-Analysis_2020-09-05.pdf

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 SWE 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 costs were estimated for the building performance program, participant costs were based on $/square foot provided by PNNL and DOE for the implementation of retuning and retro-commissioning programs.

Assumptions and data: Data from Philadelphia's Benchmarking Program was used to estimate emissions reductions from the initial building performance policy.[177]

C. 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,[178] 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.

---

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

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

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 Strategy A.

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.

D. 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 Table 11 below.

Table 11. Buildings composition by type

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

Strategy Layering: This strategy is applied after Strategies A, B, and C.

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 fossil energy use appear in the buildings sector.

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 Measure A) 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 and allocated to an electrification program. Program costs were allocated as a cost per unit of energy changed (from natural gas to electricity), as opposed to cost per unit of energy saved. 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 taken from ACEEE's

"Electrifying Space Heating in Existing Commercial Buildings" study.[179] Since electrification and cold climate heat pumps are still early technology, a 1% annual improvement curve for capital costs and associated incentives was included in alignment with air source heat pump projections from NREL's "Electrification Future's Study"[180].

E. Increase distributed on-site solar

Description

This strategy includes the installation of on-site distributed solar in both the residential and commercial sectors. On-site, distributed solar photovoltaics plays an important part in the decarbonization of the electrical grid. On-site solar implementation will be aligned with the grid decarbonization strategies outlined in Strategies N and O (found below in this section). To maximize the benefits of this strategy successfully, additional efforts will be needed, such as strategies to expand the development of solar across the Commonwealth, legislation to help develop a robust solar industry at the distributive 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 distributed solar generation through 2050, in alignment with Strategies N and O (outlined below). The modeling resulted in a clean grid (100% AEPS requirement by 2050), based on the following constraint: 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. This included a carveout to allow for at least 20% of the total solar to come from distributed solar resources.

Strategy Layering: This action is applied after Strategy N. 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.

Emissions 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.

---

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

[180] National Renewable Energy Laboratory (NREL) 2017. "Electrification Futures Study: End-Use Electric Technology Cost and Performance Projections through 2050", p. 43. https://www.nrel.gov/docs/fy18osti/70485.pdf .

Costs and Benefits Analysis

Costs associated with this measure are aligned with Strategies N and O (outlined below) as they are incorporated to the overall power sector.

Transportation Sector

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

Description

This strategy models a reduction of vehicle miles traveled (VMT) for single-occupancy vehicles by implementing travel demand strategies such as shifting travel mode choice, making travel more efficient, and increasing the frequency of telecommuting. It also incorporates projected increases in fuel economy for light duty vehicles assuming a 20% improvement between 2026 and 2050. The VMT reduction efforts are paired with land-use and development policies that incentivize and promote sustainable transportation modes (e.g., walking, biking, transit) in existing densely populated urban areas, and assume the expansion of more sustainable mobility options (bus rapid transit, carpool) to and from urban centers in the medium and long term.

The analysis uses a VMT reduction target of 3.4% by 2030 and 7.5% by 2050 compared to BAU. This estimate is based on the Pennsylvania Energy Assessment Report of 2018,[181] 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.[182]

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,[183] 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.[184] The

---

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

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

[183] DEP. 2019. Draft Report: Energy Assessment Report for the Commonwealth of Pennsylvania. http://www.depgreenport.state.pa.us/elibrary/GetDocument?docId=1451239&DocName=ENERGY%20ASSESSMENT%20REPORT%20FOR%20THE%20COMMONWEALTH%20OF%20PENNSYLVANIA.PDF%20%20%20%3cspan%20style%3D%22color:blue%3b%22%3e%28NEW%29%3c/span%3e.

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

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 Corporate Average Fuel Economy (CAFE) standards in place in 2020.

Strategy Layering: The reductions from this strategy were accounted for before Transportation Strategies G and H.

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.

G. Implement the multi-state medium-and heavy-duty zero-emission vehicle memorandum of understanding

Description

This strategy models the implementation of 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. [185] The goal of the MOU is to reach net zero emissions from MHDVs by 2050. The strategy assumes that 30% of new MHD sales will be ZEV by 2030. By 2050, all new MHDV sales are assumed to be ZEV. 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.

---

[185] Multi-state Medium- and Heavy-Duty Zero-Emission Vehicle Memorandum of Understanding. https://ww2.arb.ca.gov/sites/default/files/2020-07/Multistate-Truck-ZEV-Governors-MOU-20200714.pdf.

- 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.
- This strategy also models fuel efficiency improvements in MHDVs, leading to reductions in fuel consumption.

Method, Data, and Key Assumptions

- **Method:** 30% of medium- and heavy-duty vehicles will be ZEVs 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. Fuel efficiency improvements included are a 15% improvement for medium- and heavy-duty vehicles between 2026 and 2050.
- **Strategy Layering:** This measure used Strategy F 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.

H. Increase adoption of light-duty electric vehicles

Description

This strategy includes increasing the adoption of light-duty (LD) electric passenger vehicles including private and municipal fleet vehicles. Assuming a moderate EV adoption scenario adopted from the Pennsylvania Electric Vehicle Roadmap,[186] the strategy assumes that electric vehicles will represent 20% of the light-duty market share by 2030, rising to 70% by 2050.

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 Strategy F 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.

---

[186] DEP. 2019. *Pennsylvania Electric Vehicle Roadmap*. https://cadmusgroup.com/wp-content/uploads/2019/02/PAEVRoadmap.pdf?hsCtaTracking=5ecd2a08-e3bb-4c32-830f-a73eeb43268c%7C734499cd-191d-4114-94b9-e146eca840ad.

I. Implement a low carbon fuel standard

Description

The Low Carbon Fuel Standard (LCFS) is a market-based, fuel-neutral program designed to reduce the carbon intensity of traditional transportation fuels through a system of credits which can then be sold to regulated entities, such as importers, producers, and refiners of petroleum fuels, that are required to reduce the carbon intensity of the transportation fuels they sell in-state. Users and producers of low carbon transportation fuels earn LCFS credits through the emission reductions generated by operating their cleaner vehicle. In Pennsylvania, a LCFS-like policy would expand on the ethanol and biodiesel requirements already in place and also include zero-emission vehicles (ZEVs). While the LCFS is fuel neutral, ZEVs generate the highest LCFS credits by achieving the highest carbon reduction compared to conventional and alternative fuels.

The modeling assumes 12% carbon intensity reduction by 2030, and 22% by 2040. After 2040, no additional GHG reductions through LCFS are modeled as the carbon intensity goal is achieved by 2050 due to electrification from other transportation strategies. This measure assumes that supporting policies will be implemented to encourage fuel switching and increased electric vehicle adoption required to meet the 2050 carbon intensity targets.

Method Data and Key Assumptions

Energy Savings: As part of this strategy, changes in fuel consumption and associated emissions from fuel switching to (1) renewable diesel, (2) natural gas (i.e., compressed natural gas), and (3) 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.

Industry

J. 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 sector proportional to the GHG contribution from various sectors, as determined by EPA's 2018 Facility Level Information on GreenHouse Gases Tool (FLIGHT), 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 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 Strategy D, for the portion of industrial activity and using an 18% efficiency factor.

Strategy Layering: Reductions from this strategy were applied before Strategy L (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 on-site 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 Strategy K) 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 Strategies B and C. Since electrification and cold climate heat pumps are still early technology, a 1% annual improvement curve for capital costs and associated incentives was included in alignment with air source heat pump projections from NREL's "Electrification Future's Study."[187]

Fuel Supply

K. Increase production and use of biogas/renewable gas

Description

This strategy includes increases the production and use of biogas/renewable gas from sources including animal manure, food waste, landfill gas, water resources recovery facilities, agricultural residue, energy crops, forestry residue, and municipal solid waste. This strategy considers the potential for renewable gas and specific applications in 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

---

[187] National Renewable Energy Laboratory 2017. "Electrification Futures Study: End-Use Electric Technology Cost and Performance Projections through 2050", p. 43. Available at: https://www.nrel.gov/docs/fy18osti/70485.pdf .

Pennsylvania RNG database. Some feedstocks for RNG will be used in direct CHP applications, although the majority of available RNG supply will be injected into the pipeline to decarbonize the gas supply in Pennsylvania. The RNG supply increases to 75% of total feedstock by 2050.

Method, Data, and Key Assumptions

Potential for RNG: The analysis team's evaluation for the American Gas Foundation in 2019 found 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 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.

Table 12. Feedstock options for biogas and renewable gas

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 need.

Strategy Layering: This action interacts with Strategy L (carbon-free grid), Strategy O (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 Strategy M, which focuses 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 American Gas Foundation 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.

L. Incentivize and increase use of distributed combined heat and power

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. High-value applications are those with critical power requirements that can operate CHP systems continuously and are able to utilize all the available electricity and thermal energy. This maximizes the operational efficiency, emission reductions, and resiliency benefits associated with the CHP installations. Critical infrastructure and industrial facilities meet these criteria, making them suitable locations for CHP operations. This analysis only considers traditional topping cycle CHP applications. Other potential CHP applications, such as waste heat-to-power, require a granular site-by-site analysis, and are not considered in this strategy.

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. Instead of relying on two separate sources for electricity and thermal energy, CHP systems generate electricity and capture the heat that would otherwise be wasted. 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[188] 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 Strategy K.

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.

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). Applicable biogas air quality factors will also be considered (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.

---

[188] ICF tracks upcoming CHP installations and maintains the DOE CHP Installation Database, hosted online at https://doe.icfwebservices.com/chp.

M. 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.[189] 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 regulations,[190] 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[191] 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 derived using forecasted natural gas production, while others were derived 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

---

[189] 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

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

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

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

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

N. 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 extension for plants currently in operation; all plants currently in operation would stay online through 2050 at least with this extension. This lifetime assumption is incorporated into the carbon emissions free grid strategy below and therefore the costs and benefits associated with this strategy are incorporated in the carbon free grid strategy. Nuclear facilities can obtain two 20-year operating license extensions (known as subsequent license renewal), from the Nuclear Regulatory Commission. Two facilities have been granted second extensions, which extends their lifetime to 80 years: Peach Bottom Units 2 and 3 and Turkey Point Units 3 and 4. Four subsequent license renewal applications representing nine nuclear units are pending with the NRC, comprising nine nuclear units.

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 Strategy O.

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 in the cost analysis Strategy O.

O. Create a carbon emissions-free grid

Description

This strategy includes increasing the Alternative Energy Portfolio Standard (AEPS) to an in-state requirement of 100% by 2050 to achieve a carbon free electricity grid. The electric grid is the network that generates and delivers electricity to consumers and includes generating stations, electrical substations, and transmission and distribution power lines. Tier 1 targets and the solar carve out would be increased. The solar carve-out can be supplied by in-state grid-scale and distributed solar resources. Nuclear, storage, and fossil with carbon capture and sequestration would be added to the definition of eligible energy sources for Tier 1 as part of the portfolio of options to meet the 100% target. The Tier 2 requirement is maintained at the current level of 10% through 2050. Waste coal begins to retire as renewable and storage capacity comes online and there is no waste coal in 2050 due to the carbon free emissions limit.

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 and legislation to help develop a robust solar industry. Increasing the solar carve-out to 10% by 2030 would help increase the value of solar renewable energy credits (SRECs). This is also aligned with the DEP's Pennsylvania Solar Future Plan as discussed in the Distributed On-site Solar Strategy outlined in Strategy E. Additional consideration and efforts will be needed to ensure solar farm siting does not remove forested areas. It is important to conserve forests for carbon sequestration and storage.

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 Alternative Energy Credits (AECs) for the solar carveout and for Tier 2 resources are assumed to come from in-state generation, as required through legislation.

Strategy Layering: This strategy is applied after Strategy N. This strategy interacts with other CAP strategies 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. Costs and savings associated with reconfiguring both the distribution and transmission grids to handle larger amounts of distributed energy resources and new utility scale renewable projects were not estimated as part of this Strategy.

Agriculture

P. 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.[192] For this strategy, energy efficiency improvements are based on a report prepared for DEP by EnSave, titled "Energy Use, Energy Savings, and Energy Efficiency Policy Recommendations for Pennsylvania Agriculture."[193] This report analyzes the potential savings in electricity and fuel consumption that would result from adopting certain efficiency measures.

This strategy estimates potential energy savings for agricultural operations using the commercial energy efficiency savings modeled in the building strategies on energy efficiency (B and C). These savings estimates, based on Act 129, were applied to the technical energy efficiency potential from the EnSave report. The decreases in electricity and fuel consumption

---

[192] In addition to GHG reductions from energy efficiency measures, installation of manure digesters can also significantly reduce on-farm emissions. These reductions are estimated under the renewable natural gas strategy, "Increase Production and Use of Biogas/Renewable Gas."

[193] See https://files.dep.state.pa.us/Energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/Pollution%20prevention%20and%20Energy%20assiatance/Energy%20Use,%20Energy%20Savings,%20and%20Energy%20Efficiency%20Policy%20Recommendations%20for%20Pennsylvania%20Agriculture-2020.pdf.

were then converted to associated GHG emissions reductions. For this strategy, the measure lifetime was assumed to be 10 years.

Method, Data and Key Assumptions

Baseline Farm Energy Use: Annual baseline farm energy consumption data is based on a report by EnSave titled “Energy Use, Energy Savings, and Energy Efficiency Policy Recommendations for Pennsylvania Agriculture.”[194] 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. Thus, total emissions reductions for this strategy only include the reductions associated with decreased fuel consumption.

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 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;

---

[194] EnSave report “Energy Use, Energy Savings, and Energy Efficiency Policy Recommendations for Pennsylvania Agriculture.”

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

Q. 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 and integrated farm management to reduce the amount of GHGs emitted by farmlands. Practices could include rotational grazing, silvopasture, and organic and regenerative agricultural methods. The modeling of this strategy assumes that agricultural practices are implemented with the intention of reducing tillage intensity and thereby lowering GHG emissions.

The modeling for this strategy follows a similar methodology to the 2018 CAP. Tillage practices by crop are based on a survey of Pennsylvania farmers conducted by USDA for 2013 and 2014.[195] The modeling team assumed that the proportion of fields with no-till acreage will increase at a constant rate of 5.9% annually until it reaches 98% of all acres, the maximum potential of no-till adoption. GHG reductions are calculated for both the annual increases in carbon sequestration and the decreases in fuel consumption required for tilling.

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 percentage of acres planted by crop is consistent with the average percentage of acres planted by crop from 2011 to 2019, as obtained from the USDA National Agricultural Statistics Service QuickStats database.[196]

Tillage Adoption: The team assumed conventional tillage acres will transition to reduced tillage acres, and reduced tillage acres will transition to no-tillage acres.[197]

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,

---

[195] USDA. 2015. "Tillage Practices with Updated Alfalfa Seedings and Final Acreages." https://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Survey_Results/tillage%202014%20jan%2020125.pdf.

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

[197] 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/. https://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Survey_Results/tillage%202014%20jan%2020125.pdf.

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.

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

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." 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.

Land Use, Land-Use Change, and Forestry

R. Increase land and forest management for natural sequestration

Description

This strategy includes managing and increasing forest cover, particularly of oak-hickory forest, through a reduction of forest removal from 130-yr rotation, and additional conversion of abandoned mined lands or marginalized croplands to forests. This strategy compares the business-as-usual carbon sequestration from forested lands to the addition of natural vegetation on previously barren or marginal lands. DEP's Bureau of Abandoned Mine Land Reclamation received an award for their efforts in removing harmful coal refuse piles and restoring natural vegetation to previously functional mining lands. Since 2016, $105 million in grants have been supplied to Pennsylvania's economy for 53 projects of this nature.[198] While reforestation is not always an option (e.g., on lands that are seriously degraded), replanting native vegetation of many varieties can sequester more carbon than bare mine lands.

There are many options for increasing sequestration on natural lands beyond what is quantified in this strategy. Every year, forests and harvested wood products uptake the equivalent of over 14% of economy-wide CO_2 emissions nationwide. There is a potential to increase carbon

---

[198] DEP. 2020. "Pennsylvania Receives National Reclamation Award." Available at: https://www.dep.pa.gov/OurCommonWealth/Pages/Article.aspx?post=62.

sequestration capacity by ~20% per year by fully stocking all understocked productive forestland.[199] Additional considerations should be made for strategies to increase forest coverage and improving the timber stock on existing forest land in Pennsylvania.

The Bureau of Forestry of Pennsylvania Department of Natural Resources and Conservation (PA DCNR) identifies no-net-loss of forest cover and increasing forest acreage as major strategies in its climate change mitigation and adaptation plan.[200] Of the individual actions analyzed in this strategy, extending forest rotation and increasing the percentage of long-lived products provides the highest cumulative sequestration potential with 81% of the cumulative carbon sequestered through 2050. Of the actions that increased forestland acreage, urban open spaces offered the single highest potential with 9.2% of the total carbon sequestered. Afforestation of urban open spaces can improve urban air quality while at the same time reducing atmospheric CO_2.[201,202] Afforestation of abandoned mine lands and marginal cropland together represented 5% of the total sequestration potential. Incorporating forests on pastureland represented just 1% of the total sequestration potential due to the assumed low implementation rate.

Challenges and opportunities: A survey of forestry officials cited low funding and a lack of value attributed to forestry as challenges. It recommended increasing steady long-term funding and improving visibility and accessibility of programs. The Forest Stewardship, Forest Land Enhancement, and Forest Legacy Programs were highly rated by forestry officials.[71]

Other considerations: Pasture usually shifts to forest by reclassification when growing trees gain at least 10% canopy. Given the potential pastureland offers, silvopasture might be worth further examination. Opportunity costs and potential leakages from reduced timber harvests will also attribute to ecosystem services, and lack of public awareness as major impediments. Suggestions for improvement need to be examined. Advancements in high-resolution forest carbon measurement will improve accounting, monitoring, and management of the state's carbon stocks.

Oak-hickory (*Quercus*/*Carya*) is the most prevalent forest type in Pennsylvania covering 54% (3,682,640 ha) of the state's area.[73,203] An assessment of habitat suitability, colonization potential,

---

[199] Domke et al. (2020). Tree planting has the potential to increase carbon sequestration capacity of forests in the United States. https://www.pnas.org/content/117/40/24649.short.

[200] PA Department of Conservation and Natural Resources (DCNR). 2018. "Climate Change Adaptation and Mitigation Plan." https://www.dcnr.pa.gov/Conservation/ClimateChange/Pages/default.aspx

[201] Nowak, David J. "The effects of urban trees on air quality." USDA Forest Service (2002): 96-102.

[202] Irga, P. J., M. D. Burchett, and F. R. Torpy. "Does urban forestry have a quantitative effect on ambient air quality in an urban environment?." Atmospheric Environment 120 (2015): 173-181.

[203] McWilliams, W. H., J. A. Westfall, P. H. Brose, S. L. Lehman, R. S. Morin, T.E. Ristau, A. A. Royo, and S. L. Stout (2017). After 25 years, what does the Pennsylvania Regeneration Study tell us about oak/hickory forests under stress? In: J. M. Kabrick, D. C. Dey, B.O. Knapp, D.R. Larsen, S.R. Shifley, H.E. Stelzer, eds.

and adaptation traits showed that the oaks and hickories have moderate to high adaptability in the state under high and low emissions scenarios for the year 2100.[204] Under a changing climate scenario, white oak (*Quercus alba*), black oak (*Quercus velutina*), and chestnut oak (*Quercus prinus*) were shown to have high coping capabilities in their habitats in the state. Shagbark hickory (*Carya ovata*), pignut hickory (*Carya glabra*), and mockernut hickory (*Carya alba*) were capable of coping under these conditions as well.[204] More than 60% of oak/hickory forests will need management and policy guidelines to prevent intense browsing from deer, which could be a major challenge as seen with the Pennsylvania Oak Forest Regeneration project.[203]

Method, Data and Key Assumptions

Additional sequestration strategies

In addition to the business-as-usual scenario, eight sequestration strategies were considered and three were assessed for their sequestration potential, described below.

1. Harvest extension and increase in long-lived wood products

The U.S. Department of Agriculture Forest Service PA DCNR evaluated 10 management scenarios for the state's forests. Their methods for quantifying forest sector carbon trends, mitigation potential, and substitution benefits as described in Dugan (2018) involved a systems-based approach in a carbon modeling framework. This included:

- An ecosystem model based on growth and yield (the Carbon Budget Model for the Canadian Forest Sector (CBM-CFS3 configured for Pennsylvanian Forest types),
- A lifecycle harvested wood products model (the Carbon Budget Modeling Framework of Harvested Wood Products, CBMF-HWP), and
- published displacement factors for substituting wood fiber for fossil fuel-based energy or products.
- Site-specific input data of forest characteristics and harvesting was obtained from the DCNR forest inventory, the Forest Service's Forest Inventory and Analysis (FIA) database, and remotely sensed disturbance and land-use change data.

Among the scenarios, the highest climate mitigation was projected from extending harvest rotations, reducing harvests, and increasing the proportion of long-lived wood products (including saw logs and panels by 5% at the cost of pulp and paper). This strategy is based on the cited work, Dugan, A., et al. (2018). *Assessment of Forest Sector Carbon Stocks and Mitigation Potential for the State Forests of Pennsylvania* presents modeling scenarios crafted to identify

---

Proceedings of the 20th Central Hardwood Forest Conference; 2016 March 28-April 1; Columbia, MO. General Technical Report NRS-P-167. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 280-290.

[204] Iverson, L. R., Prasad, A. M., Peters, M. P., & Matthews, S. N. (2019). Facilitating Adaptive Forest Management under Climate Change: A Spatially Specific Synthesis of 125 Species for Habitat Changes and Assisted Migration over the Eastern United States. Forests, 10(11), 989. doi:10.3390/f10110989.

strategies that may lead to gains in atmospheric carbon sequestration and carbon storage on forest lands. Scenarios such as very short rotation lengths, which may be practical if PA develops robust bioenergy markets and extending minimum rotation ages of PA forests beyond the typical 80 years were presented. Results from this work suggest that extending rotations to 130 years or more is one of the best strategies for increasing forest carbon. This conclusion is based on data inputs provided to the models and the modeling parameters used. These inputs and parameters did not include robust environmental, social, or economic data to evaluate the trade-offs associated with the scenarios. For example, the current age class distribution of PA's forests is heavily skewed to the mature forest age classes. What this means is young forest is under-represented in PA to the detriment of many wildlife species that depend on these forests for habitat. Extending the rotation of PA forests, which in effect delays the creation of young forest, will likely lead to even less young forest and this trade-off was not evaluated. Additionally, the impact on the PA timber industry that could result from a decreased availability of harvestable timber was not considered in these models either. Although extending the minimum rotation of PA forests appears to be a viable strategy for increasing forest carbon, a thorough evaluation of the associated trade-offs is necessary to ensure there are not any unintended negative impacts.

This scenario is expected to result in a decrease in annual harvest removals because the extension of harvest rotations results in fewer trees being cut each year. About half of this benefit was attributed to the 5% increase in long-lived wood products; increasing the proportion of harvested wood going to such uses further could be a significant driver for greater carbon mitigation from forest management and use. This scenario was projected to have the greatest cumulative mitigation benefit from 2020 through 2050, and therefore was selected for this RGGI strategy. This strategy reduced emissions statewide compared to the BAU scenario by an estimated 6%. This percentage was applied to the business-as-usual scenario for each year to obtain the additional sequestration potential.

2. Afforestation of abandoned mine land

It was assumed that 75% of the total 101,174 ha (250,000 acres) abandoned or legacy mine land in Pennsylvania was available for afforestation. A 5-year implementation period (2022 to 2027) was assumed. Over the project period (2022 – 2050), the average of non-soil forest carbon stocks (live tree, standing dead tree, understory, dead down wood, and forest floor) was estimated based on timber volume and carbon stocks in Oak-Hickory stands in the Northeast reported by Smith et al. (2006). The estimated carbon sink was further reduced by 50% to account for growth rates and carbon pools on abandoned mine lands being lower than natural forests. The annual sequestration rate of 0.65 tonnes CO_{2e}/yr over 35 years, was obtained from the average carbon stocks. Oak-hickory stands were chosen due to their dominance in the state's forests, high-value to the timber industry, and being the most important source of mast for wildlife.

The annual carbon storage was calculated as the sum of annual carbon sequestration on the cumulative planted area.

Costs of site preparation were estimated between $6,175/hectare to $8,645/hectare (pers. comm., Michael Jacobson, Penn State). Costs depended on the extent of land preparation needed, particularly, the depth of ripping required for legacy mine lands with compacted topsoil and the number of trees to be planted.

3. Sequestration from Reforestation – Forests Open Space, Marginal Croplands, Grasslands, Pasture, Shrubs, and Urban Open Space.

Definitions of the land use types followed the National Land Cover Database and the area of opportunity for each strategy was obtained from Cook-Patton et al. (2020).[71]

Carbon stocks, annual sequestration rate, and cumulative annual sequestration followed methods described above for the afforestation of mined lands with a few exceptions:

- No allowance was made for slow growth as done for abandoned mine lands. An annual sequestration rate of 1.31 $MTCO_2e$/year over 35 years was used.
- The implementation area was 40% of pastureland with a maximum of 5% per year.

Applicable Emission Factors

Carbon sequestration factors for reclaimed forest land are based on the study "Early Tree Growth in Reclaimed Mine Soils in Appalachia USA."[205]

Costs and Benefits Analysis

Economic metrics were not estimated for this strategy due to the complexity of quantifying costs and benefits associated with natural lands.

Zero opportunity cost was assumed for abandoned mine lands as they are considered to be underutilized.

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.

[205] Dallaire, K., & Skousen, J. (2019). Early Tree Growth in Reclaimed Mine Soils in Appalachia USA. Forests, 10(7), 549. https://www.mdpi.com/1999-4907/10/7/549.

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 is the estimated effect of the policy, and only these incremental costs are modeled in REMI. 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. 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 disposable personal income for Commonwealth residents.

REMI provides a detailed set of macroeconomic results, including industry-specific changes to employment, output, and income. REMI also provides context into commodity price and population changes, as well as economic leakage (e.g., how competitive Pennsylvania is compared to surrounding states, and how many jobs may move into Pennsylvania or may move to other regions). For this analysis, the key metrics of interest are employment, gross state product, and disposable personal income.

- **Employment:** Employment comprises estimates of the number of jobs, full-time plus part-time, by place of work for all industries.
- **Gross state product:** The market value of goods and services produced by labor and property in Pennsylvania.
- **Disposable personal income:** Total after-tax income received by persons, i.e., the income available to persons for spending or saving.

The analysis team used the REMI model and individual action-level inputs to model the CAP strategies and estimate the macroeconomic impacts. 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. Electrification strategies tend to result in increasing energy costs for consumers because of fuel shifts from natural gas to electricity. Distributed solar generation investments result in changing energy savings as consumers can use their self-generated power.

Transportation sector: Investments in light-, medium-, and heavy-duty electric vehicles (a negative impact on consumer budgets) result in increases in electricity bills, but also gasoline and diesel savings and lower maintenance costs. Investments in electric charging infrastructure generates local construction and manufacturing jobs. VMT reduction strategies lower consumer costs, but also result in less revenue for gas and service stations. Implementation of a low carbon fuel standard would result in changing revenue for the fossil fuel industry.

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) result in economic impacts. This analysis uses the Jobs and Economic Development Impact models from National Renewable Energy Laboratory to identify industry-specific impacts for modeling in REMI. The analysis uses IPM to estimate ratepayer impacts from changing generation mix, credit costs, and carbon price impacts.

Agricultural sector: Savings on diesel and gas expenditures from encouraging best agricultural practices result in some capital expenditures and some savings associated with changing fuel consumption.

Environmental Justice and Equity Analysis

Environmental justice and equity were analyzed and integrated at multiple points in the climate action planning process related to both GHG reductions and adaptation. At the beginning of the process, DEP engaged with the Office of Environmental Justice, and DEP continued to seek feedback and input from this Office throughout the development of the CAP to ensure alignment with Pennsylvania-wide environmental justice principles and polices.

GHG Reductions

To identify and prioritize GHG reduction strategies, DEP first worked with ICF and the CCAC to develop an initial potential list. This list was refined and then prioritized based on a set of criteria, one of which was Environmental Justice and Equitable Implementation Opportunity Benefits. This criterion considered the potential to improve environmental justice, and to design implementation strategies that may result in more equitable outcomes.

Additionally, during the early phases of the CAP development, DEP worked with ICF to evaluate different existing and potential programs around the country that focused on providing equitable benefits. This screening helped support the prioritization analysis and informed the development of strategies to specifically consider equitable access to program benefits and implementation. Strategy-specific considerations related to equity are included in each of the recommended implementation considerations.

Defining Environmental Justice and Equitable Implementation

Environmental justice embodies the principles that communities and populations should not be disproportionally exposed to adverse environmental impacts. Historically, minority and low-income Pennsylvanians have been forced to bear a disproportionate share of adverse environmental impacts. Addressing environmental justice means that ensuring that all Pennsylvanians, especially those that have typically been disenfranchised, are meaningfully involved in the decisions that affect their environment and that all communities are not unjustly and/or disproportionally burden with adverse environmental impacts.

Equitable implementation embodies the principle and commitment to promote fairness and justice in the formation of public policy that results in all residents—regardless of age, race, color, sex, sexual orientation, gender identity, religion, national origin, marital status, disability, socio-economic status or neighborhood of residence or other characteristics—having opportunity to fully participate in and benefit from program or policy opportunities.

GHG reduction strategies have the potential to advance equity by improving air quality in disproportionately impacted communities, reducing energy bills in low-income households through building weatherization and strategic electrification, increasing transit options in areas with low accessibility, and more.

In general, any given GHG reduction strategy's capacity to benefit or detract from equity depends in part on how the strategy is designed and implemented. Strategies focused on increasing electric vehicle adoption provide a good example of the complexities of determining equity in GHG reduction strategies. There are equity benefits inherent to the strategy, as reduced tailpipe emissions lead to lower air pollution near roadways, thus helping to mitigate disparities in exposure to air pollutants from vehicles.[206] A counterargument to the tailpipe emission reduction benefit is that increased adoption of electric vehicles also leads to increased electricity generation, so potential disparities in exposure to stationary-source air pollution from power plants must be considered as well. However, the electricity generation sector is decarbonizing and eliminating criteria pollutants at a much faster rate than the transportation sector; this, combined with the greater efficiency of electric vehicles in total energy usage versus internal combustion engine vehicles, makes vehicle electrification a preferable strategy to lower net emission impacts from transportation.

[206] Literature shows that that "populations on the lower end of the socio-economic spectrum and minorities are disproportionately exposed to traffic and air pollution and at higher risk for adverse health outcomes." See Pratt, et al. 2015. *Traffic, Air Pollution, Minority and Socio-Economic Status: Addressing Inequities in Exposure and Risk*.

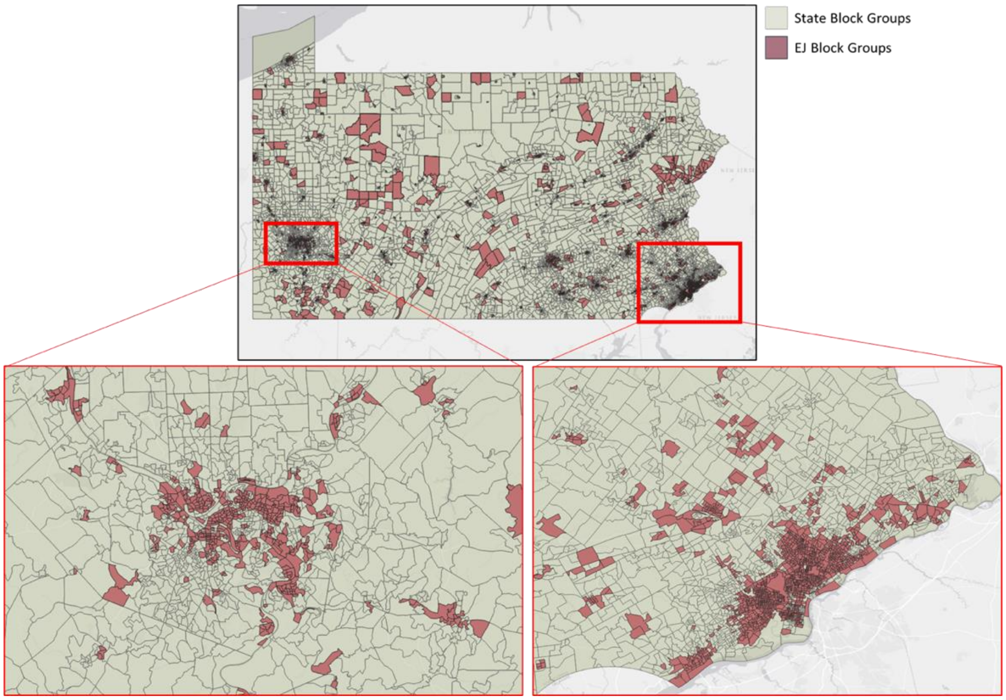
Finally, a strategy can be made more equitable by providing a suite of clean energy options to consumers. Using once again the example of electric vehicles, current incentives that rely on tax credits largely benefit population segments whose income allows for large tax breaks. That is why point-of-sale vouchers or special low-income loan programs are increasingly being implemented to benefit those who cannot afford high up-front costs and do not have the credit requirements for a loan. Car-sharing programs that incorporate electric vehicles are also becoming a popular strategy to provide access to clean mobility without requiring private vehicle purchases. These solutions are becoming popular in low-income and other disadvantaged communities, and they are well received by the public as they have additional co-benefits in reducing road and parking congestion and advancing sustainable land-use.

Adaptation

The adaptation strategies presented in this CAP are based on analyses conducted for the 2021 Climate Impacts Assessment. To evaluate potential environmental justice and equity consequences in the Impacts Assessment, Pennsylvania Environmental Justice Areas are used to represent already disadvantaged populations. An EJ area is any census tract or block group where 20% or more of individuals live in poverty, and/or 30% or more of the population is minority. EJ areas serve as a proxy for already overburdened areas. This indicator does not capture all impacts on overburdened populations (for example, it does not capture impacts on overburdened populations not located in EJ areas). Nonetheless, it is valuable to begin study of structural disadvantages, and this assessment also draws on other information to supplement it where possible given its limitations.

Figure 55 shows where EJ areas (at the block group level) are located across the Commonwealth, with a zoomed-in focus on Philadelphia and Pittsburgh where higher population density makes block group shading less legible in the state map.

Figure 55. Environmental Justice census block groups in Pennsylvania



This analysis is not a comprehensive bottom-up assessment. While based solidly on evidence from past IAs, recent literature, and updated climate projections, the decision-centered approach recognizes uncertainty and emphasizes practicality. Rather than aiming for a perfect characterization of risk, this approach focuses on gathering information at a sufficient level of detail to facilitate prioritization of adaptation actions that can be taken to reduce risks. Further, it provides the foundation for DEP to easily revisit the results of the assessment as needed as priorities or circumstances change.

Using information from the Impacts Assessment it was determined that warmer temperatures and increased flood risk are expected to disproportionately impact overburdened and vulnerable populations. These populations may both be more at risk to impacts from these hazards and face greater challenges to managing those risks. Therefore, the CAP focuses one specific adaptation pathway and set of strategies on reducing these risks in Environmental Justice communities. This approach helps ensure that strategies in place to adapt to climate change are providing benefits and reducing risks equitably for Pennsylvanians.

APPENDIX C. CLIMATE ADAPTATION STRATEGIES

Each adaptation strategy pathway presents examples of adaptation strategies that could be used to address priority risks in each focus area. This appendix contains additional example strategies, as well as outside resources, that the State and other actors could draw on for inspiration or guidance when moving toward implementation.

Additional resources that DEP may consider for ideas of strategies and implementation timing or frameworks include:

- 2018 Pennsylvania Climate Action Plan[207] (available here)
- Growing Stronger: Toward a Climate-Ready Philadelphia[208] (available here)
- North Carolina Climate Risk Assessment and Resilience Plan[209] (available here)
- The City of Providence's Climate Justice Plan[210] (available here)
- State of Oregon Climate Equity Blueprint[211] (available here)
- USAID Fast Track Implementation of Climate Adaptation[212] (available here)
- Preparing for the Regional Health Impacts of Climate Change in the United States[213] (available here)

Addressing the Impacts of Increasing Heat and Flooding on Health

Table 13 provides a list of adaptation strategies for this focus area, some taken from the 2018 Pennsylvania Climate Adaptation Plan and others adapted from outside sources.

Table 13. Adaptation strategies for addressing the impacts of increasing heat and flooding on health

Strategy	Actor
Establish metrics and key actors and responsibilities for tracking health data	State agencies, municipalities, researchers, community-based organizations
Identify coordination and partnerships needed to achieve public health goals	State agencies, municipalities

207 See: https://www.dep.pa.gov/Citizens/climate/Pages/PA-Climate-Action-Plan.aspx.

208 See: https://www.phila.gov/media/20160504162056/Growing-Stronger-Toward-a-Climate-Ready-Philadelphia.pdf.

209 See: https://files.nc.gov/ncdeq/climate-change/resilience-plan/2020-Climate-Risk-Assessment-and-Resilience-Plan.pdf.

210 See: https://www.providenceri.gov/wp-content/uploads/2019/10/Climate-Justice-Plan-Report-FINAL-English.pdf.

211 See: https://www.oregon.gov/lcd/CL/Documents/Climate-Equity-Blueprint-January-2021.pdf.

212 See: https://www.climatelinks.org/resources/fast-track-implementation-climate-adaptation.

213 See: https://www.cdc.gov/climateandhealth/docs/Health_Impacts_Climate_Change-508_final.pdf.

Strategy	Actor
Identify education and trainings needed for climate and health awareness and action	State agencies, municipalities, researchers, community-based organizations, sector representatives
Identify range of infrastructure opportunities and actors needed to mitigate climate and health risks	State agencies, municipalities, researchers, community-based organizations
Identify key plans, policies, regulations to address public health needs	State agencies, municipalities
Identify opportunities for improving baseline health	State agencies, municipalities, community-based organizations
Provide funding and personnel for monitoring needs	State legislature
Monitor climate and health metrics (e.g., track disease and water quality concerns relevant to health; monitor for new pathogens likely to expand their ranges)	Researchers, municipalities
Identify priorities from climate and health monitoring data	Researchers, state agencies, community-based organizations
Publicize findings from climate and health monitoring, in formats accessible to both expert and non-expert audiences; increase data quality and availability and develop new surveillance databases (e.g., monitoring climate-sensitive morbidity)	Researchers, Department of Health, municipalities, community-based organizations
Develop plan to act on findings from climate and health monitoring data (e.g., identify priority health risks and education needs, incorporate infrastructure needs into Capital Improvement Plan or Program [CIP] or other planning, map data to prioritize community heat studies, etc.)	State agencies, municipalities, community-based organizations
Update community health assessments to include climate change and health data	State agencies, municipalities, researchers, community-based organizations
Map locations of vulnerable populations to target community outreach and support in extreme events	State agencies, municipalities
Increase access to healthy and local food, and support local farmers and food network	Municipalities
Educate health-care professionals and the public on climate-related health risks	State agencies, municipalities, health sector
Fund and support school programming for education on heat-related risks (e.g., ticks, heat stroke) and how to avoid them	State agencies, County and Municipal Health Departments, State Health Centers, municipalities
Train local health department staff to assess capacity to integrate flood risks into existing plans and operations	State agencies (e.g., OEJ), County and Municipal Health Departments
Increase access to resilient infrastructure and invest in nature-based solutions, particularly in communities at high risk to infrastructure-related health risks (e.g., flood risks from poorly protected infrastructure at low elevation)	State agencies, municipalities
Retrofit cooling shelters, incentivize urban greening for builders that in-zone, and prioritize support for areas with strong urban-heat-island effects	State agencies, municipalities
Fund flood mitigation grants, prioritizing vulnerable populations and locations at particular risk to flooding	State legislature

Strategy	Actor
Develop local, community-informed risk mitigation plans	Municipalities, community-based organizations
State provide funds and technical support for heat wave plans and flood risk mitigation and post-disaster programs; show commitment to community organizations	State legislature, state agencies
State revise policies to support health given projected increased heat and flood risks	State legislature
Review worker safety guidelines to identify workers with greatest heat risk; revise guidelines to protect health	State agencies, municipalities
Review zoning codes, create system to update to reflect climate projection data	State agencies, municipalities, researchers
Strengthen climate change public health messaging and outreach (methods, content, and target groups and events)	State agencies, County and Municipal Health Departments, municipalities, community-based organizations
Engage vulnerable groups through existing community networks to conduct outreach and education on climate and health risks, understand concerns, and solicit potential solutions	Municipalities, County and Municipal Health Departments, State Health Centers, community-based organizations
Coordinate on health and emergency efforts across sectors	State agencies, municipalities
Require that emergency preparedness plans include coordination and communication among critical stakeholders. These stakeholders may include community organizations, local businesses, local health departments, hospitals and other health-care delivery facilities, utilities, and local government	State legislature, state agencies, municipalities
Review local occupational health and safety standards to identify occupations at risk due to climate change, and revise as necessary	State agencies, researchers, municipalities
Develop a web-based resource hub to provide information and technical resources on public health and climate change preparedness	State agencies, researchers, community-based organizations
Develop strategies and goals for government to support communities where there has historically been a strained relationship, to be able to effectively support public health needs in those communities	State agencies, municipalities, community-based organizations
Integrate citizens' knowledge of public health needs and opportunities into research, risk assessments, and planning	Municipalities, researchers, community-based organizations

Addressing the Impacts of Increasing Heat and Flooding on Overburdened and Vulnerable Populations

Table 14 provides a list of adaptation strategies for this focus area, some taken from the 2018 Pennsylvania Climate Adaptation Plan and others adapted from outside sources.

Table 14. Adaptation strategies for addressing the impacts of increasing heat and flooding on overburdened and vulnerable populations

Strategy	Actor
Establish metrics and key actors and responsibilities for tracking equity of impacts and solutions	State agencies, municipalities, researchers, community-based organizations
Identify opportunities for community capacity-building	Municipalities, community-based organizations
Identify key policies, regulations, and plans to incorporate environmental justice	State legislature
Identify vulnerable communities, and community organizations to partner with	State agencies (e.g., OEJ), municipalities, community-based organizations
Identify needed education and trainings on equity risks of extreme heat and flooding	Municipalities, community-based organizations
Identify coordination needs to bring together key actors around justice goals	State agencies
Incentivize and facilitate further interdisciplinary collaboration (e.g., between public health providers, scientific researchers, and community-based organizations) to develop a better understanding of the relationship between climate change, diseases, and which populations are most vulnerable and/or most impacted	State agencies (e.g., OEJ)
Invest in community capacity-building and seek out local knowledge	Municipalities, community-based organizations
Create and fund program to provide grants for community-based resilience projects (e.g., flood-protected community center with a roof garden)	State legislature
Fund a statewide forest conservation easement program	State legislature
Support vulnerable populations when integrating climate risks into key plans	Municipalities, community-based organizations
Identify and study communities' informal heat wave event coping practices; support and strengthen in emergency plans, given increased risk of heat waves going forward	Municipalities, community-based organizations
Improve infrastructure in most vulnerable communities to reduce impacts	Municipalities
Plant trees and create designated cooling shelters in areas with many low-income families	Municipalities
Increase flood mitigation grant funds (e.g., for businesses, public parks); reduce barriers to application	State legislature, state agencies, municipalities
Develop and implement trainings and education; act on findings (e.g., provide funds and support to local organizations)	State agencies, municipalities

Strategy	Actor
Train homeless shelter staff on heat hazards; provide tools to address related risks (e.g., tick repellant)	Municipalities, community-based organizations
Provide homeless shelter staff and faith leaders with resources for the community about on increased risks of extreme floods	Municipalities, community-based organizations
Establish program or funding streams to fund and implement strategies	State legislature, state agencies
Develop and maintain databases to track metrics; act on findings	State agencies, municipalities, researchers
Regularly update climate hazard resource hub for non-expert audiences	Municipalities, researchers, community-based organizations
Mandate that emergency plans must be developed and tested with input from community stakeholders, including stakeholders or representatives (e.g., advocacy group leaders) from overburdened populations	State legislature
Ensure that post-shock-event recovery work strengthens the capacity of overburdened and vulnerable populations to adapt to future events	Municipalities, community-based organizations
Evaluate overburdened and vulnerable populations' current flood insurance coverage and access to insurance that protects against climate hazards; develop actionable goals to improve accessibility and awareness of insurance for those populations; work to implement	State legislature, state agencies, municipalities, community-based organizations
Partner with HR department to improve diversity, equity and inclusion (DEI) at all levels of staffing and contracting; review and strengthen workplace supports for staff with a wide range of backgrounds, lived experiences, and identities	State legislature, state agencies, municipalities
Evaluate efficacy of existing communications, alert and early warning systems, and response plans for emergency response (to heat hazards and flooding) in addressing needs of overburdened and vulnerable populations, informed by suggestions and needs identified by community-based organizations; strengthen based on those suggestions	State agencies, municipalities, community-based organizations

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

Table 15 provides a list of adaptation strategies for this focus area, some taken from the 2018 Pennsylvania Climate Adaptation Plan and others adapted from outside sources.

Table 15. Adaptation strategies for addressing the impacts of increasing temperatures and flooding on forests, ecosystems, and wildlife

Strategy	Actor
Support initiatives to reduce recreational and commercial fishing in already stressed fisheries; lightly fished stocks are likely to be more resilient to climate change impacts than those heavily fished.	State agencies, conservation organizations
Increase monitoring of species and habitats, particularly those that are vulnerable, against an established baseline over the long term.	State agencies, conservation organizations
Develop and use ecological flow thresholds to manage fish withdrawals so they do not increase thermal stress on sensitive species and habitats.	State agencies, conservation organizations
Conserve and enhance areas representing the full range of wildlife and fish habitats and promote connectivity (e.g., using land exchanges, conservation easements, leases; by removing barriers) to allow species to migrate to suitable habitats	State agencies, conservation organizations
Promote forest conservation, reforestation, and urban tree canopy expansion on private and public lands through various means, including funding a statewide forest conservation easement program.	State legislature, state agencies, municipalities
Develop a central database to store relevant ecosystem data.	State agencies, universities, conservation organizations
Establish a statewide monitoring and research network of academics, civil society, and citizen scientists to establish baseline conditions and monitor ecosystem factors	State agencies, universities, conservation organizations
Review legal, regulatory and policy frameworks that govern protection and restoration of wildlife and fisheries habitats and identify opportunities to improve their ability to address climate change impacts.	State agencies, conservation organizations
Adopt regulations that provide streamflow levels necessary to ensure the resilience and ecological integrity of both warm-water and cold-water streams	State agencies, municipalities
Manage fish populations to increase resilience to interdecadal environmental variability by determining the minimum number of age classes needed for resilience and then managing age structure accordingly.	State agencies
Increase monitoring of stocks and maintain basic fish sampling.	State agencies, conservation organizations
Conduct climate change risk assessments for native fisheries to identify species and populations that are at risk and include potential economic losses and the costs of adaptation measures.	State agencies, conservation organizations

Strategy	Actor
Where appropriate, restore or enhance stream channels to create cold-water refuges	State agencies, municipalities, conservation organizations
To improve overall landscape resilience, create nature preserves as large as possible and maintain habitat connectivity across landscape	State agencies, municipalities, conservation organizations
Increase funding for land conservation	State legislature, state agencies
Establish a carbon banking and trading system that pays landowners to plant and manage working forests on both private and public land	State legislature, state agencies, conservation organizations
Educate recreational land users about the importance of climate change impacts on ecosystems and the dangers of illegal hunting and fishing, pollution, and development	State agencies, municipalities, conservation organizations
Promote sustainable land use planning and development. Intelligent land use planning promotes practices that provide the critical elements for quality of life for residents as well as protects and restores naturally functioning ecosystems and agriculturally productive lands.	State agencies, municipalities

Addressing the Impacts of a Warmer and Wetter Climate on Agriculture

Table 16 lists adaptation strategies for this focus area, some taken from the 2018 Pennsylvania Climate Adaptation Plan and others adapted from outside sources.

Table 16. Adaptation strategies for addressing the impacts of a warmer and wetter climate on agriculture

Strategy	Actor
Reestablish/establish a network of agro-meteorological stations statewide to collect climate observations, including estimates of evapotranspiration, to support research and development of agricultural practices.	State agencies, municipalities
Increase climate change education and outreach to agricultural producers and enable delivery of applied research and decision-making tools	State agencies, municipalities
Create or enhance existing networks to facilitate the rapid transfer and adoption of new knowledge and technologies to help farmers adapt to a changing climate	State agencies, USDA, universities
Expand regional planning initiatives, especially in agricultural areas, focusing on agricultural security zones and local food security.	State agencies, USDA, agricultural groups
Promote awareness of low- or no-cost land available from the USDA Farm Services Agency's Conservation Loan Program for infrastructure adaptation (e.g., irrigation, livestock facilities).	State agencies, agricultural groups, USDA
Improve understanding of how climate change will affect the intensity and distribution of weeds, insects and diseases	State agencies, USDA

Strategy	Actor
Integrate potential climate change impacts (e.g., changes in weeds, diseases, pests) into current detection, monitoring and integrated pest management efforts	State agencies, USDA
Provide information to the agricultural community to enable farmers and growers to modify agricultural practices and to adapt to new pests and diseases.	State agencies, researchers, community-based organizations
Provide financial incentives and support for agriculture best practices including sales or property tax exemptions, rebates, reduced agricultural insurance rates, and, pricing systems that reward conservation (i.e., seasonal pricing).	State legislature, insurance industry
Introduce agricultural insurance requirements to factor climate risk reduction benefits of management best practices	State legislature, insurance industry, USDA
Support economic and cooperative structures that transfer risk from farm and bank like Community Supported Agriculture (CSA)	USDA, state agencies, agricultural groups
Analyze drivers of current crop planting behaviors (e.g., crop prices, insurance availability) to determine ways to modify behaviors	Universities, state agencies, USDA
Develop and disseminate seasonal climate forecasts	Universities, state agencies, USDA
Support research and development of more crop rotations and crop mixtures.	Universities, state agencies, USDA
Learn about management strategies for invasive species (including pests/pathogens) from states where they are already established.	Universities, state agencies, USDA
Increase adoption of techniques that replicate natural systems' mechanisms for pest control, windbreaks, and disease management.	State agencies, USDA, agricultural groups
Expand technical assistance programs to help farmers make decisions about sustainable crops and production practices (e.g., Penn State Ag. Extension, NRCS, county conservation districts, county extension agents).	State agencies, USDA, agricultural groups universities
Promote sustainable land use planning and development. Intelligent land use planning promotes practices that provide the critical elements for quality of life for residents as well as protects and restores naturally functioning ecosystems and agriculturally productive lands.	State agencies, municipalities
Develop and enhance emergency response plans to manage significant pest outbreaks that harm human health, the environment and the economic viability of the agriculture sector	State agencies, USDA
Expand integrated farm management and conservation planning	State agencies, USDA, agricultural groups
Research the benefits of periodic fallowing for active floodplain acres to maximize floodplain storage, nutrient processing, and sediment capture (or to prevent major scour damage).	USDA, state agencies, agricultural groups, universities
Use improved LIDAR elevation data and information to guide farmers considering relocation of vulnerable farming operations.	USDA, state agencies, universities
Promote agriculture that is compatible with periodic flooding	USDA, state agencies, agricultural groups

Strategy	Actor
Provide incentives for farmers to increase storage capacity by using farm ponds/large cisterns to capture runoff for irrigation needs, animal wash water, and cooling water.	State agencies, USDA
Purchase wetland easements on marginal and flood-prone agricultural lands to diversify grower income, buffer productive lands from flood events, and improve the environmental services provided by these lands.	Agricultural groups, USDA, state agencies, agricultural producers
Support research on practices (e.g., cover cropping, conservation tillage, soil fertility) to enhance soil's water- holding capacity and GHG reductions.	USDA, state agencies, universities
Establish an information clearinghouse for growers on water conservation technology.	USDA, state agencies, universities
Develop decision support tools to assist farmers in determining the optimal timing and magnitude of investments to cope with climate change.	USDA, state agencies, universities

Addressing the Impacts of Increasing Average Temperatures on Recreation and Tourism

Table 17 provides a list of adaptation strategies for this focus area, some taken from the 2018 Pennsylvania Climate Adaptation Plan and others adapted from outside sources.

Table 17. Adaptation strategies for addressing the impacts of increasing temperatures on recreation and tourism

Strategy	Actor
Increase tree and vegetation in areas with outdoor activity to provide shade. Also consider building other shade structure and other areas to cool off (e.g., incorporate misters)	State agencies, municipalities, outdoor recreation businesses
Create a business ombudsman or technical assistance center for affected recreational industries and establish a source of grant funding or tax incentives to help industry and municipalities transition from winter to summer activities	State legislature, state agencies
Educate facilities about diversification opportunities for more warm-weather or cold weather activities (e.g., ski slopes can maintain mountain bike trails for warm weather) with consideration of environmental impacts	State legislature, state agencies
Invest in green infrastructure at recreation sites such as constructions with heat-resistant materials; heat-resistant materials for paved assets; energy efficiency improvements.	Recreation site operators including municipalities and state agencies (DCNR)
Establish a statewide monitoring/research network to monitor ecosystem factors, such as physical changes, species distribution, weather conditions, and general ecological conditions	State agencies, universities
Ensure that newly planted vegetation can handle increased temperatures and heavy rainfall events; review maintenance schedules to adjust watering, mowing, and other practices.	Recreation site operators including municipalities and state agencies (DCNR)

Strategy	Actor
Assign more medical staff at places where people congregate and recreate in hot weather and may suffer heat stress	Recreation site operators including municipalities and state agencies (DCNR)
Establish a formal climate change working group building on existing partnerships	State agencies
Develop safer places to jog at night or early morning and add more water fountains and shade along routes.	Municipalities

Addressing the Impacts of Flooding on Built Infrastructure

Table 18 provides a list of adaptation strategies for this focus area, some taken from the 2018 Pennsylvania Climate Adaptation Plan and others adapted from outside sources.

Table 18. Adaptation strategies for addressing the impacts of flooding on built infrastructure

Strategy	Actor
Improve the accuracy and technological capabilities of flood forecasting, early-warning and emergency-preparedness systems.	State agencies, universities
Collaborate with trade associations and the insurance industry to develop specification improvements that ensure building and infrastructure designs are more resilient to flooding.	State agencies, municipalities
Update flood insurance rate maps and other regulatory tools that rely on FEMA maps to reflect evolving risks from climate change.	State agencies, municipalities
Adopt insurance mechanisms and other financial instruments, such as catastrophe bonds, to protect against financial losses associated with infrastructure losses.	State agencies, municipalities, utility industry
Work with local jurisdictions to incorporate consideration of climate change into ongoing land use planning efforts (e.g., growth management, development planning).	State agencies
Implement new or modified policies (e.g., zoning regulations, tax incentives, rolling easements) that encourage appropriate land use and reduce repetitive losses.	Municipalities
Determine critical public buildings that will be impacted by coastal and inland flooding and recommend appropriate adaptation strategies that will not adversely impact natural resources.	Municipalities, state agencies
Upgrade or implement design improvements for flood-control structures (e.g., levees, flood walls) that protect existing critical infrastructure.	Municipalities, state agencies
Encourage owners and operators of critical energy infrastructure to evaluate vulnerability to the impacts of climate change, including the risk of damage and the potential for disruptions and outages from flooding	State agencies
Evaluate ability and need to harden or relocate transfer stations and related solid waste infrastructure located in areas likely to be affected by sea level rise or inland flooding.	Municipalities

Strategy	Actor
Enhance the preparedness of transportation, utilities, and emergency service providers to respond to weather-related emergencies through increases in funding and emergency training.	State legislature, state agencies
Determine vulnerable transportation routes and transportation infrastructure that may adversely impact natural resources and human mobility under future climate change scenarios.	Municipalities, state agencies
Require maps of areas vulnerable to future flooding in applications for new development	State agencies, municipalities
Provide individual landowners with better information about their ecologically based flood-proofing options and the rapidly changing location of floodplains as shifts in land use and climate affect erosion and flooding.	State agencies, municipalities
Work with the Budget Office and Planning Commission to integrate climate change into capital programming and budgeting, and to determine appropriate free board and flood proofing construction requirements.	State agencies
Collect post-event cost data for events that are both above and below the national hazard declaration threshold.	State agencies
Develop decision tools to evaluate replacement, modification, and design life for infrastructure.	State agencies, universities
Preserve open space in flood hazard areas and channel migration zones.	Municipalities, state agencies
Reduce impervious surface and implement green infrastructure to promote infiltration, evapotranspiration, and reuse.	Municipalities
Encourage development of structures and infrastructure in areas that are unlikely to be eroded or flooded by more intense and frequent storms, instead of in vulnerable areas.	Municipalities
Enhance natural flood management capacity by developing regulations and incentives to encourage development projects to restore or create flood storage.	Municipalities
Consider new mortgage products similar to PACE loans to incorporate the costs of adaptation into private property transactions.	Municipalities, state agencies
Undertake long-term managed relocation or elevation of existing structures in vulnerable areas.	Municipalities
Design buildings to maximize resilience by placing on higher floors those assets and services most likely to be impacted by flooding or those most expensive to replace	Municipalities
Develop a stormwater billing system to create a more equitable fee structure that more closely reflects the costs of managing stormwater for individual properties.	Municipalities
Use green infrastructure practices (no regrets strategies) such as broad adoption of rain barrels and rain gardens, wetland development, green roofs, bio retention and green streetscapes to retain runoff and filter pollutants cost effectively.	Municipalities
Provide tax credits for green infrastructure implementation, reduced stormwater fees to reward greater site permeability and rebates for downspout disconnection.	Municipalities, state agencies

Strategy	Actor
Prioritize the retrofit of transportation infrastructure while undergoing maintenance and repair.	Municipalities, state agencies
Support a regional evaluation of transportation and utility networks that are vulnerable to flooding to determine hot spots or weak links that would cause significant disruption to the regional economy and quality of life.	State agencies

Addressing the Impacts of Landslides on Built Infrastructure

Table 19 provides a list of adaptation strategies for this focus area, some taken from the 2018 Pennsylvania Climate Adaptation Plan and others adapted from outside sources.

Table 19. Adaptation strategies for addressing the impacts of landslides on built infrastructure

Strategy	Actor
Systematically identify and map landslide-prone areas statewide.	State agencies
Develop public education and outreach on landslide risks and how to adapt to them.	State agencies
Develop best management practices, policies and incentives for land management that reduces landslide risk.	State agencies
Adjust routine operations, maintenance and inspection, and capital budget expenses to prepare for more landslides.	State agencies
Develop an asset management framework with a rating system that considers the impact of route failure and impacts of disruptions.	State agencies
Improve collaboration on anticipating and communicating landslide risks.	State agencies, municipalities
Coordinate emergency responses to landslide events.	State agencies, municipalities
Incentivize development in safe locations and discourage development in vulnerable locations.	Municipalities
Improve and develop landslide mitigation funding mechanisms	State agencies, municipalities
Map landslide risk along transmission line rights-of-way.	State agencies, municipalities
Relocate public buildings and critical infrastructure systems such as power plants, water lines, or telephone sub-stations to less vulnerable areas.	State agencies, municipalities, utilities
Fund the maintenance landslide maps.	State agencies
Increase the coverage of landslide maps.	State agencies, municipalities, utilities
Improve routine maintenance of roads and consider operational changes.	State agencies, municipalities
Conduct trainings for municipal staff about climate-resilient land use.	State agencies

APPENDIX D. COMMENTS FROM THE CLIMATE CHANGE ADVISORY COMMITTEE

The Pennsylvania Climate Change Act (Act 70 of 2008) requires that the Climate Action Plan "identifies areas of agreement and disagreement among committee members about the Climate Change Action Plan." Letters documenting members' areas of "agreement and disagreement" have been solicited from CCAC appointees, and are included in this appendix. The views presented in these letters do not necessarily represent those of the DEP.

July 15, 2021

Lindsay Byron
Energy Programs Office
Department of Environmental Protection
400 Market Street
Harrisburg, PA 17101

Re: CCAC 2021 Climate Action Plan

Krug Architects
Architecture Energy Sustainability
318 Parke Hollow Lane
West Chester, PA 19380-2283

610-299-3353

AStevensKrug@gmail.com

Dear DEP and Energy Office,

This is the fourth edition of the PA Climate Action Plan (CAP) that I have been involved with. On behalf of the PA Climate Change Advisory Committee (CCAC), I would like to thank DEP for listening to us and for having the CCAC engaged in the development and review of the CAP. Our request to have more opportunities to review the CAP than the prior 2018 edition was much appreciated. The approach to each edition of the CAP has intentionally been different to address issues as they change over time. This edition provides a road map to achieve the Greenhouse Gas (GHG) reduction targets in Executive Order 2019-01, as well as resiliency and adaptation strategies.

The goals are to reduce GHG by 26% by 2025, and 80% by 2050 (from 2005 levels). There are 18 primary GHG reduction strategy categories discussed and modeled in the 2021 CAP to demonstrate how the Commonwealth can potentially achieve these significant changes. Ten (10) of these GHG reduction strategies are near term. To prepare for the future, the potential benefits, concerns, and costs were analyzed, as well as opportunities to adapt to the changing climate. The report provides advice and many examples on how policy can help maintain prosperity, growth, and provide a sound approach to climate change.

In the building sector, I support the adoption of the latest building codes for not only energy efficiency, but for reasons of resiliency, health, and safety. I hope that we communicate to Pennsylvania communities that they have the option to use stretch codes if they wish to incentivize people to go beyond the basic code and get more value, density, and environmental benefit as a result. The CAP models clearly show there is an economic benefit to energy efficiency, as well as making Pennsylvania businesses more valuable and competitive.

A couple of the most important items we need more of in the future are a real commitment to *net-zero buildings* and *alternative fuel*

Steve Krug
AIA, PE LEEDap, AEE Fellow
Principal, Architect

vehicles. In order to achieve the goals set out in the CAP and Executive Order 2019-01, the Commonwealth will have to be designing and building many more net-zero buildings and more alternative fuel infrastructure for electric vehicles (EVs). C-PACE financing and other helpful tools will encourage and promote the implementation of healthy high-performance net-zero buildings and EV infrastructure.

The 2021 Climate Action Plan (CAP) maps out a challenging approach to reducing the use of fossil fuels over the next 30 years in Pennsylvania. There are many new opportunities for people to get involved and continue to position Pennsylvania as a leader in the energy sector, albeit there are some exciting/scary transitions required. Hydrogen technology and renewable natural gas are two areas that policy makers should investigate further, because these technologies provide use of Pennsylvania's strong liquid and gas infrastructure and machines. Additionally, the oil and gas industry can show the world their advanced drilling technologies in geothermal and blended fuels for CHP opportunities, just to name a few of the opportunities for businesses and industry to adapt.

2020 was a challenging year and I want to thank the members of the Climate Change Advisory Committee for sharing their valuable knowledge and time. I want to thank DEP and the ICF team for listening to the CCAC advise and for all their hard work. Also, I want to thank AIA Pennsylvania and Krug Architects for their support of my involvement in the CCAC. The CCAC has made some impact over the years, as we have seen several legislative and executive actions. We still have a long way to go.

For example, one of the results of the 2018 CAP, which raised the issue of cap and trade, has been the possibility that Pennsylvania may join RGGI, the Regional Greenhouse Gas Initiative. The Pennsylvania RGGI proceeds could help transition communities, business, and industry to the next level.

Finally, I am looking forward to future discussions about *low embodied carbon procurement policies* and the economic benefits that Pennsylvania can show businesses how to shift our use of energy to new technologies and lead the way as we adapt to a changing climate. Strong building renovation incentives will help lead the charge by reusing existing buildings.

Sincerely,

A. Stevens Krug, AIA, LEED™*ap*, PE, AEE Fellow
Principal
Krug Architects

Marc Mondor, AIA, LEED Fellow, CEM, WELL AP, USGBC Faculty
Principal, evolveEA
President AIA Pennsylvania 2020
Vice Chair, PA Climate Change Advisory Committee
6020 Broad Street
Pittsburgh, PA 15206

Lindsay A. Byron, P.G., CC-P
Environmental Group Manager
Energy Programs Office
Department of Environmental Protection
Rachel Carson State Office Building
400 Market Street
Harrisburg, PA 17101

July 23, 2021

2021 Pennsylvania Climate Action Plan Comments

Dear Ms. Byron and the Entire DEP,

Thank you for the opportunity to provide comment to the 2021 Pennsylvania Climate Action Plan. I would like to thank PA State Senator Jay Costa (D - Forest Hills) for my appointment to this important Committee, (CCAC) and to acknowledge Stevens Krug for his steady leadership as Chair of the CCAC, my reliable Alternate Joe Morinville, and the rest of my colleagues on the CCAC. I appreciate the opportunity and confidence placed in me for my participation in the Climate Action Plan process over the last six years, and to the CCAC for their trust in elevating me to the role of Vice Chair. I would also like to thank my firm **evolveEA**, where I serve as Managing Principal, and **AIA Pennsylvania**, where I serve several Board roles, for their support of my service.

The Pennsylvania Climate Action Plan carries weight as an objective evaluation and as an instrumental document. The 2021 Climate Action Plan includes an exhaustive tally of the sources of carbon in the Commonwealth, addresses adaptability measures to address climactic forces already in progress and now addresses the human health impacts of climate change. The Plan is unique in its scope, in the intensity of its evaluation, in the productive back and forth among the selected stakeholders, and its specificity to the uniqueness of our Commonwealth of Pennsylvania, both with regards to our own annual Impact Assessment and to our economic and demographic forces.

We are pleased with the results of this collaboration leading to the 2021 Pennsylvania Climate Action Plan and would like to use our perspective to provide the following comments for constructive consideration.

The Regional Greenhouse Gas Initiative is essential to Pennsylvania's Climate Action. Just as Executive Order 2019-01 in 2019 established Pennsylvania carbon goals that, in essence, gave purpose to the 2018 Climate Action Plan, the Regional Greenhouse Gas Initiative (RGGI) will provide a similar underpinning to the 2021 Climate Action Plan. Implemented by gubernatorial executive order, 2019-07, RGGI will provide a price on carbon other than simply first cost, which is an essential component to driving down fossil fuel use. Another essential benefit to the implementation of RGGI is the expected proceeds of hundreds of millions of dollars per year, which will be used for coalfield justice, renewables programs, energy efficiency programs, education, and other priorities currently being established by the DEP.

A price on carbon must be established and maintained. RGGI will establish a price on carbon emissions from electric generating units. Currently we can all emit for free, paying money for the fuel, but not for the sink. Carbon emissions have a cost that must be acknowledged in order for emissions to be valued. Using the market forces that drive our economy, those who economize emissions should be rewarded, while the actions of the profligate should be reflected by a more comprehensive financial cost.

Health and Triple Bottom Line are baked into this Plan. The 2021 Climate Action Plan looks to public health impacts related to climate change to a much greater extent than in previous plans. While drought and growing season impacts have led to less robust, predictable or quality crop yields - which impact public health - this Plan takes urban heat island impacts of climate change into account. The stressors of longer Summer stretches of hot humid days in urban areas prone to urban heat island effects has a magnified impact upon denser and aged populations on fixed incomes. The Triple Bottom Line accounting intended in this Plan accounts for health benefits. Less carbon emissions typically means cleaner air, more physical activity and less illness, all of which have great, measurable social returns and create more well-being for the citizens of the Commonwealth.

Photovoltaics play a more prominent role in this Plan. The application of solar photovoltaics creates energy, offsets air pollution, creates local jobs and decreases demand charges. Monocrystalline panels, the most common, consist of durable, solid state construction with no moving parts and only a 20% degradation over their 25-year lives. Rooftop mounted solar panels increase the asset value of the buildings and land upon which they are installed. Solar panels also contribute to resiliency, able to assist decentralized power generation and storage for use in grid emergencies, which helps increase resiliency.

Fugitive Emissions are not addressed in this Plan. The legacy of Pennsylvania having been an energy juggernaut for centuries is that of abandoned wells across our rich energy landscape. According to the DEP, there are over 200,000 orphaned and abandoned wells that emit gases, largely methane. Methane is a far more potent greenhouse gas than carbon dioxide, and so is not addressed in this Plan. These wells are typically not tracked or documented and have been overgrown, making them difficult to identify, locate or monitor. The DEP has a budget for finding and capping these wells, but all will admit that this budget is laughably inadequate.

Fracking has been a carbon reduction silver bullet, but all costs are not fully accounted. The advent of hydraulic fracturing over the last two decades, notably in the Marcellus Shale formation, has yielded a gas extraction revolution, creating immense output, jobs and wealth. This has had the positive effect of lessening overall emissions due to the direct displacement of coal production. However, the immediate and long term ground-level and water-table impacts of fracking are not mentioned in this report due to the scope of the Climate Action Plan, a lack of consensus and the need for long term study.

Nuclear power has long been a bane of environmentalists who may now look the other way. The Climate Action Plan calls for nuclear production levels to remain constant over the next decades in spite of the recent decommissioning of Three Mile Island and projected decommissioning of the Beaver Valley nuclear power plant, removing a third of our current nuclear generation. Like coal, nuclear power is effectively being displaced by inexpensive and abundant natural gas. The net effect will be that a no-carbon emission generation method will be replaced by one that does create emissions. Nuclear power has always been unpopular among environmentalists, but in light of the increased importance of meaningful carbon reduction goals, particularly those specific to the scope of this Plan, this potent carbon-free electrical generation is more appealing than in recent decades. This Plan makes assumptions about the continuous production of nuclear power, but, as stated in the Plan, will not be possible without legislative assistance.

Buildings and built form influence carbon in many ways. Commercial and residential buildings account for approximately 40 percent of emissions nationally, but read as about 18 percent in this Plan due to being lumped in as part of consumption. However, building efficiency due to improved building codes (Act 36 of 2017), improved construction technology, increased adoption of building performance rating systems such as LEED, and reduced costs for building-mounted photovoltaics allow buildings to be more energy-efficient while also improving occupant health. Building energy efficiency, healthy interiors and on-site energy generation make buildings high-performing investments. Settlement patterns are also very important, as the transportation associated with access to buildings is markedly less for denser patterns of development, with mass transit and walkability providing carbon reduction and health benefits.

Lastly, but perhaps most importantly, **there is urgency in the application of the strategies of this Plan**. The 2021 Impact Assessment for Pennsylvania authored by ICF with input from Penn State University for the Pennsylvania Department of Environmental Protection states that Pennsylvania temperatures will rise on average by 5.9 degrees Fahrenheit by 2050, in just over a generation! This astonishing number is over 3 degrees Celsius at a time when there is agreement that a 2 degree Celsius rise will cause irreparable harm to our entire planet's biotic systems. This very rapid rate of change will have enormous and cascading impacts on every single aspect of our lives in Pennsylvania – food production, pest migration, air quality, hydrology, human health, air conditioning demand, infrastructure and livability, to name a few - making the adaptability measures of the Plan all the more relevant and timely.

Thank you again for your attention and for the good and important work that the DEP is performing.

Sincerely,

Marc Mondor; AIA, LEED Fellow, USGBC Faculty, WELL AP
Principal and co-founder, evolveEA
President, AIA Pennsylvania 2020
Vice Chair, PA Climate Change Advisory Committee

Kerry Campbell
Program Manager Energy Programs Office
Pennsylvania Department of Environmental Protection
Rachel Carson State Office Building
400 Market Street
Harrisburg, PA 17101

July 22, 2021

Dear Mr. Campbell,

It is my pleasure to share these comments regarding the 2021 update to the Pennsylvania State Climate Action Plan. As an initial matter, I wish to note that I was appointed to the Pennsylvania Climate Change Advisory Committee (CCAC) by Governor Wolf as an individual, not as a representative of a specific organization or industry. Thus, my comments reflect my personal opinion and are not necessarily reflective of the views or opinions of my employer or any other organization with which I am affiliated.

My comments are as follows:

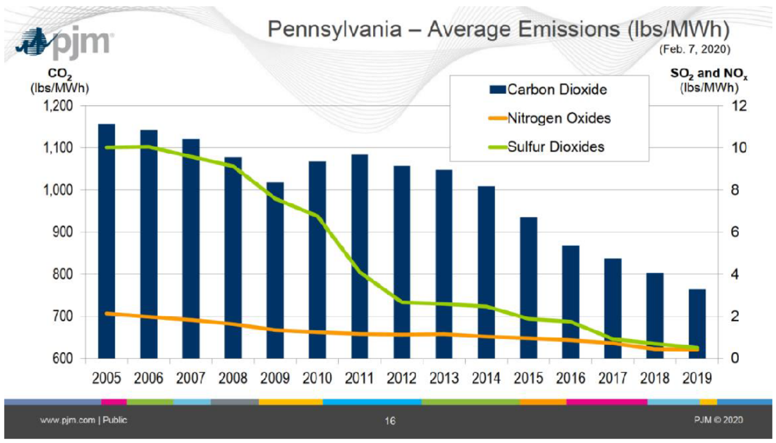
Emissions Reduction Target
This document maintains the greenhouse gas (GHG) emissions reduction target established in the 2019 plan of a 25% reduction in GHG emissions by 2025 and an 80% reduction by 2050, below 2005 levels. Prior to 2019, the state's earlier climate action plans included a list of recommended actions, but no target. I strongly support inclusion of a reduction target. The Climate Action Plan can be thought of as a roadmap; the target sets the end point to which the map is leading.

Since the time that Governor Wolf set Pennsylvania's aspirational targets in his 2019 Executive Order, other states, countries, and businesses have set more aggressive goals. For example, President Biden in April 2021 established a national GHG reduction goal of 50-52% below 2005 levels by 2030, approximately double Pennsylvania's goal. I support the Department of Environmental Protection's (DEP's) inclusion of a goal and encourage the Department to continually evaluate and increase this target in future iterations of the plan.

Inclusion of Actions that Potentially Increase Fossil Fuel Use
I am hesitant to endorse a plan that includes recommendations that increase the use of fossil fuels. Specifically, page 76 recommends that the state "Incentivize and Increase Use of Distributed Combined Heat and Power." The plan qualifies that expanded use of combined heat and power (CHP) should occur "particularly for high-value applications such as critical facilities (e.g., hospitals) and industrial facilities. High-value applications are those with critical power requirements that can operate CHP systems continuously and are able to utilize all the available electricity and thermal energy."

The annual increase in natural gas usage associated with this recommendation is estimated at ~48,906 Bbtu in 2050. As shown in Figure 18 on page 34, the emissions reductions associated with this measure are quite modest compared to other actions in the plan.

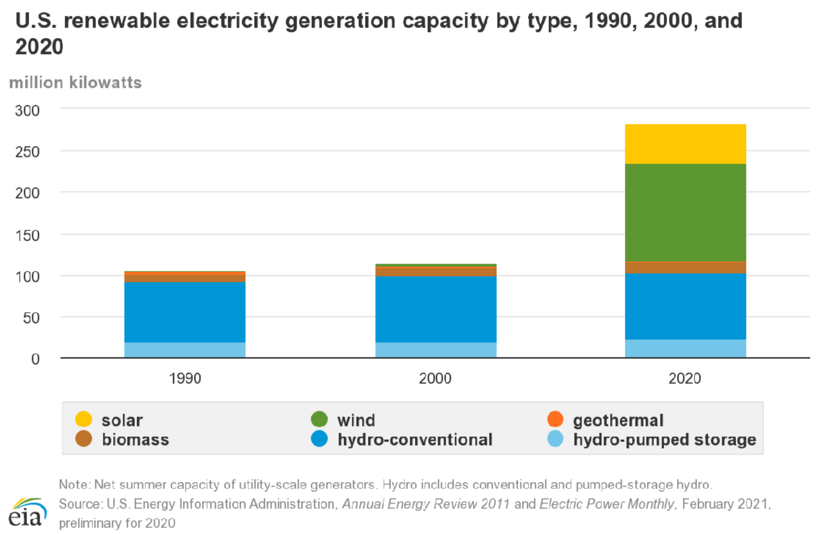
As grid electricity continues to decarbonize, additional thought should be given to whether the state should incentivize distributed fossil fuel based infrastructure. For example, the figure below shows the decrease in emissions per megawatt hour of electricity for Pennsylvania between 2005-2019.[1]



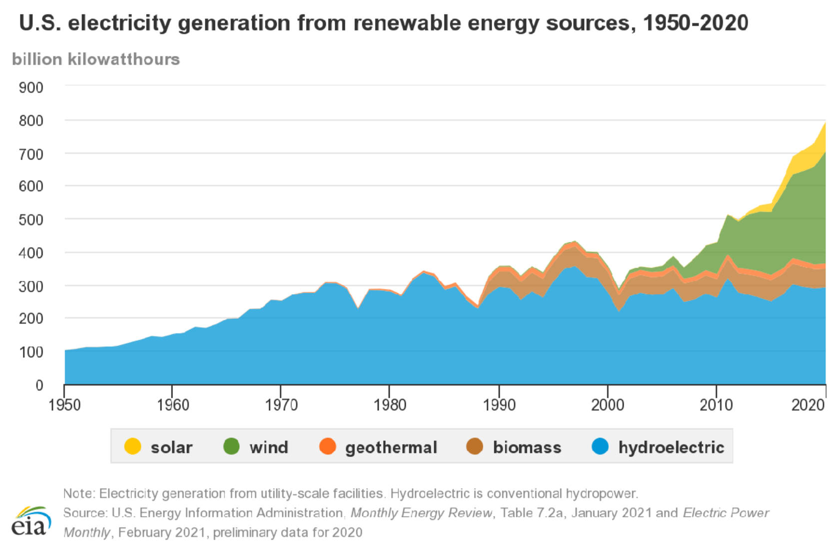
While fuel switching from coal to natural gas played a large part in achieving these emissions reductions, natural gas is not emissions free. The grid continues to decarbonize through the addition of zero-emissions sources, primarily the additional capacity of renewable energy sources. For example, see the below graphic from the Energy Information Administration showing the rapidly increasing capacity of wind and solar.[2]

[1] See Page 16. https://files.dep.state.pa.us/Air/AirQuality/AQPortalFiles/Advisory%20Committees/Air%20Quality%20Technical%20Advisory%20Committee/2020/10-15-20/20201015%20PJM%20Presentation%20to%20PA%20DEP%20AQTAC%20on%20Generation%20Dispatch.pdf

[22] www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php



Additionally, the proportion of energy generated by renewable resources is growing rapidly in recent years.[3]



[3] https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php

Natural gas will likely be a part of the power generation profile in the U.S. for many years due to its availability and dispatchable attributes. At least in the near term, it will be an important energy source for balancing variable sources of energy, like solar and wind.

Using natural gas in an efficient, centralized power plant has the potential to be equipped with carbon capture technology in the future. In contrast, distributed CHP applications that use natural gas are not emissions-free. CHP will make sense for some customers from an economic or reliability standpoint, based on their unique circumstances. However, as I have noted in Committee meetings in the past, I question whether the state should be incentivizing projects that lock in the use of fossil fuels well into the future, as part of a climate action plan.

Accessibility to the Public

Finally, I encourage the Department to consider how to make this and future plans more accessible to the general public. The current plan, at a length of 200+ pages is overwhelming in scope and is hardly accessible to the average Pennsylvanian. It is my understanding that DEP intends to produce a companion document that is shorter, more concise, uses more common language, and is intended to be easy to understand to a resident or business owner. I strongly support this intention and offer my assistance in my role as a CCAC member.

In closing, I would like to thank the staff of the DEP for the time and effort that has gone into this plan and for the opportunity to participate in the process. I look forward to continuing to support the implementation of this plan, along with the drafting of future plan updates as a member of the Climate Change Advisory Committee.

Sincerely,

Lindsay A. Baxter
Appointed Member
Pennsylvania Climate Change Advisory Committee

COMMENTS REGARDING THE 2021 CLIMATE ACTION PLAN AND RELATED DOCUMENTS

TERRY R. BOSSERT

Introduction:

I appreciate the opportunity to comment on the Department's 2021 Climate Action Plan (CAP) and to have my comments appended to the CAP. I also appreciate the time and effort devoted by Department personnel to keep the Climate Advisory Committee informed on the progress of the Department's development of the CAP as well as the Climate Impacts Assessment (IA). Since there was no similar opportunity to append comments to the IA, I also include, herein, some brief comments regarding that report. There are several recommendations in the CAP with which I agree, at least in concept, and I discuss them more fully below. However, in many instances I believe the CAP does not present a full or balanced picture. Having worked at the Department twice in my career it pains me to say so, but in some areas, I believe the plan to be disingenuous. These comments represent my personal views and opinion and should not be attributed to any past, present or future clients, employers, or any other person or entity.

The Faulty Foundation:

Unfortunately, the CAP builds on a faulty foundation. That faulty foundation is the IA. As I previously noted when asked to comment on the IA, the IA fails to comply with the statutory requirements of Act 70. Act 70 requires that the IA assess the "impacts" of climate change. Impact is a neutral word and can mean something positive or something negative. However, the IA unlawfully defines "impact" only as an "environmental hazard." Accordingly, the IA only looks at the potential negative results of climate change and essentially ignores any positives. Moreover, the IA fails to meet the statutory requirement that a "diversity of views" be reflected in the report. Many scientists who are not "deniers" nonetheless question the severity of the predicted impacts suggested by some of the models. Those views are not represented.

A few examples will illustrate the one-sidedness of the IA. We are told that the average annual temperature will increase by 3.3 degrees C. by 2050. However, we are not told that there are currently places where the temperature has historically been at those levels and humans have survived quite nicely. The IA decries the alleged demise of the ski industry without anything more than passing reference to outdoor recreation or water sports. I lived in Georgia and enjoyed waterskiing in October. The IA states that the growing season will be "altered", apparently not wanting to say that it will increase, without discussing what new crops may become possible and what economic benefit may follow. The IA assumes that Pennsylvania now has the perfect climate and that any change is bad.

Lastly, the IA is an insult to the citizens of Pennsylvania. It assumes that citizens will care about climate change only if dire personal consequences are alleged. Most of the "consensus" studies recognize that even the most extreme predictions assume less impact in the temperate zones.

If climate change will cause catastrophic harm elsewhere in the world, that should be sufficient reason for the world to act.

What Does the CAP Accomplish?

Notwithstanding all the hard work that went into preparing the CAP it is hard to see what it will accomplish. Frankly, the CAP seems untethered to world reality. President Biden and John Kerry have both said that implementing the entire climate agenda of the Biden administration will not solve their expressed climate concerns. Without other major countries, such as China and India, making the same scale of reductions the *national* climate plan will have no positive global impact. Therefore, what impact could Pennsylvania's plan have on global climate concerns? Moreover, there is nothing in the plan that suggests that its implementation will produce any climate benefit for Pennsylvanians. The CAP makes bold statements about "shielding" Pennsylvania from the worst impact of climate change but fails to show how any or all of the strategies will accomplish that. One often hears that we should "do our part" notwithstanding the inaction of many others. I agree we should do our part – at the right time. If one were a pitcher on a baseball team and the outfielders were not playing, but were standing around watching you, would you continue to pitch ("do your part") while the score mounted? Of course not. Why should Pennsylvanians endure the disruptions to the economy and lifestyle when no benefit will be realized? When there is a reasonable basis to believe that "doing our part" will make a difference, that is the time to act.

It is apparent that the strategies suggested by the CAP will cause economic and lifestyle disruptions, and in many cases are not cost effective, in the normal sense of that term. The fact that the CAP needs to redefine "cost effective" speaks volumes. The CAP states: "A strategy does not have to have greater benefits than costs to be cost-effective, rather the costs have to be worth the benefits gained—some benefits are worth paying for." (CAP p. 25) Thus making cost effectiveness a subjective determination. Clearly, the CAP is not about cost effective strategies, but rather, is about strategies the someone thinks "are worth paying for" notwithstanding the cost.

Where I Agree – Sort of:

I support many of the energy efficiency recommendations not because of climate concerns alone but also because they prevent waste and excess cost. Having been raised by parents who came of age during the Great Depression, I believe that measures that increase efficiency and minimize the waste of energy or other resources are meritorious even without consideration of any climate change benefits. However, I do not believe that the CAP adequately evaluated the recommendation that building electrification be "incentivized" – which I assume means subsidized in some form. First, the CAP shows that this strategy will have a cost of more than $500.00 per million tons of CO_2e reduction, as well as other negative economic consequences. Additionally, there is no evaluation of the relative heating efficiency of gas heating versus electric heating, nor any consideration of the threat to home energy resiliency caused by relying on one power source.

Likewise, actions that derive energy from waste materials are inherently worthwhile. Renewable natural gas produced from waste materials is worthy of consideration, if for no reason other than it makes productive use of waste material. However, the CAP suggests that somehow the CO2 produced from the combustion of RNG will behave differently in the atmosphere. The CAP states that combusting biomass produces "biogenic carbon dioxide" that "has a modified impact on emissions because of its biological nature." (CAP p. 74). IEA Bioenergy suggests that the C02 emitted from burning biomass is no different and does not have a different impact, it is merely from a different source.[1] It is from a biogenic source, but it is still plain old CO2. Moreover, the IEA assessment is based on combustion of biomass from vegetation, not gas from landfills where some of the decomposing materials were not part of the so-called natural carbon cycle. Despite the "spin" in this section, the use of RNG is a worthy strategy.

I support the transition to electric vehicles, primarily because that transition will result in the reduction of criteria pollutants, especially in urban areas. However, the transition must be done in a carefully planned and paced manner. Recently, California asked its residents to refrain from charging their electric vehicles, demonstrating the dangers of rushing headlong into "feel good" strategies without adequate planning and resources. In addition, the recently revealed problems with Philadelphia's electric busses provide a cautionary note that overly eager moves may backfire and become costly to taxpayers. Nonetheless, a carefully paced transition to electric vehicles is a reasonable goal.

Unfortunately, the CAP does not analyze the benefits to be obtained from the waste-related strategies. Reducing waste, increasing recycling, and expanding beneficial reuse of waste are worthwhile goals. However, many of the Department's existing regulations and policies create barriers to reaching those goals. DEP should examine its existing programs to identify regulations or policy positions that inhibit the beneficial use/recycling of waste as part of the next CAP.

There is no doubt that nuclear energy should be part of the Commonwealth's energy portfolio. However, the CAP suggests merely maintaining nuclear generation at current levels – perhaps to support a specific political agenda item. It seems odd to me that a plan that proposes to de-carbonize the grid does not recommend an increase in the levels of nuclear generation and propose a strategy to do so with some of the emerging technologies around smaller nuclear facilities. It is hard for me to believe that a climate plan is serious about reducing CO2 emission,

---

[1] "burning fossil fuels releases carbon that has been locked up in the ground for millions of years, while burning biomass emits carbon that is part of the biogenic carbon cycle." https://www.ieabioenergy.com/iea-publications/faq/woodybiomass/biogenic-co2/.

as opposed to funneling taxpayer money to friends and allies, if it fails to support additional nuclear generation.

Carbon Emission-free Grid:

By far the largest GHG reductions would come from the creation of a carbon emission-free electric grid. The projected reductions are more than double the reductions projected from the next highest category. However, this strategy carries significant economic costs, and the CAP fails to adequately evaluate the impediments to implementation. In short it is unrealistic. This strategy relies heavily on significant but uncalculated subsidies to "renewable" power generation sources. Interestingly while suggesting significant command and control legislation and subsidies, as well as favorable permitting schemes for renewable facilities, the CAP then suggests that carbon capture and sequestration will have to compete with these subsidized facilities on a least cost basis, again tilting the playing field in favor of the Department's preferred sources. Pennsylvania is a major electricity exporting state. Whether it will remain so is if this strategy is implemented is not discussed. While advocating the wholesale conversion to wind and solar facilities, the CAP fails to determine the number of wind and solar facilities that will be necessary to meet the goal; how much land area they will require; and where they will be located. Nor is there any discussion regarding the CO2e emissions that will result for the mining of necessary minerals or from the manufacture of the components of renewable facilities. One often hears suggestions regarding cumulative impacts or lifecycle CO2 analysis for fossil fuel facilities. The same should be done for a strategy that proposes a radical transformation of the electric generation grid. Given the growing opposition to some "renewable" facilities, whether from environmentalists, municipal governments, or local citizens, it is difficult to take this strategy seriously.

Additional Issues:

The following are some specific additional concerns I have regarding the CAP:

1. Jobs. On page 29 the CAP references one million "cumulative job-years." The footnote makes clear that one person holding a job for 5 years yields 5 job-years. In other words one new job was created. However, throughout the CAP the term used is simply "jobs". One cannot tell whether the alleged job gains are actual new jobs or job-years.
2. Electric vehicles. Although I support the gradual transition to electronic vehicles, the CAP fails to discuss a major revenue loss that transition will produce. As purchases of gasoline and diesel fuel decline so will the revenue from the taxes imposed on these fuels. Even though these fuel taxes are the primary source of highway maintenance funds, the CAP fails to address this lost revenue as a cost.
3. Vehicle miles traveled. Once again, the CAP offers VMT reduction as a viable strategy without any meaningful way to achieve the goal. All of the implementation recommendations assume an urban setting. The history of other efforts to reduce VMT

should tell us that the public is not yet ready to accept constraints on their movements. This strategy should be dropped as unrealistic.

4. Electrification strategies. The CAP contains aggressive electrification recommendations for both transportation and buildings. GHG reductions are projected to be 21% and 14% respectively. Obviously, these electrification efforts with increase the demand for electricity. While projecting a combined 35% reduction in GHG, due in large measure to electrification strategies, the CAP also projects that electric generation GHG emission will decline by 34%. This seems to be an unrealistic expectation.

Conclusion:

It is obvious that much hard work went into the production of the CAP and some of the recommended strategies have inherent merit. However, its fatal flaw, in my opinion, is its failure to show how implementing these strategies, some of which will require radical changes, will benefit the global climate, or produce any benefit for Pennsylvanians without similar efforts by other states and countries.

Terry R. Bossert

July 22, 2021

COMMENTS ON THE 2021 PENNSYLVANIA CLIMATE ACTION PLAN

Luke Brubaker, Member

Pennsylvania Climate Change Advisory Committee

July 22, 2021

I appreciate the opportunity to offer the following comments regarding the final version of the 2021 Climate Action Plan (2021 CAP) for Pennsylvania.

As background, I currently serve as State Director for Pennsylvania Farm Bureau (PFB) in District 8, representing membership in Dauphin, Lancaster, Lebanon and York Counties. PFB is a statewide general farm organization with local county Farm Bureau affiliates that are active in 64 of Pennsylvania's 67 counties. PFB provides political advocacy, information and educational services, and professional assistance to farm and rural families throughout the Commonwealth. Each year, PFB engages in an extensive grassroots process for development and adoption of the organization's public policy positions. I hope that my comments on the 2021 CAP will generally reflect the views expressed in the adopted policy positions of the organization's members. PFB is the state affiliate of the American Farm Bureau Federation.

Assuming that projections of climate-based impacts to weather, land conditions, and other natural conditions offered by ICF in its 2021 Climate Impacts Assessment are accurate, I would first note my belief that the 2021 CAP's projections of future consequences and challenges to be incurred from these conditions by farming operations in the Commonwealth are reasonably accurate and should be a significant concern to Pennsylvania farmers. Sales of Pennsylvania's farm products directly provide some $7.8 billion annually to the Commonwealth's economy. Along wiith supporting processing enterprises, direct economic output from Pennsylvania's agriculture industry totals $81.5 billion annually.

Exposure of Pennsylvania farms to recurrent episodes of excessive rainfall and flooding or to excessive and prolonged periods of drought would have potentially devastating economic consequences for both producers who directly market fresh commodities and field crops to consumers and producers who market livestock and poultry products wholesale to commercial purchasers and food processors. Any single episode of extreme rainfall or drought can destroy meaningful yield of field-based commodities on a farm in a production year. For producers of fresh fruits and vegetables and producers of marketed grain and field crops, the harsh economic impacts from loss of an entire year's product yield should be obvious.

Destruction of field crops through natural disasters can have similar and harsh economic impacts on animal agricultural operations as well. Animal agricultural operations, especially dairy operations, rely heavily on their own ability to produce field crops or tap a reliable supply of locally grown crops to supply feed for their animals in order to effectively manage their cost of production. Destruction or serious reduction in crop yield from flood or drought in a growing year sharply increases the cost these farmers will need to incur to replace the feed supplies lost for that year. Not only do farmers lose money from the cost they incurred in their failed attempt to produce feed crops. They will also incur high out-of-pocket costs in securing the quantity and type of feed they need for their animals from a more distant source.

For producers of fresh fruits and vegetables, availability and employment of a dependable and productive workforce is also key to their continued success and viability. Continuous and prolonged periods of excessive heat temperatures can seriously discourage potential employees from seeking work in farm fields and can adversely affect their willingness to remain employed in field work. Failure to secure a competent and willing workforce can be especially devastating to producers during critical production periods, such as harvesting time when products to be timely harvested to avoid serious financial loss from deterioration in product quality.

Recognition of these potentially adverse impacts and consequences to Pennsylvania's agriculture industry in the 2021 CAP is important and should be kept consciously in mind by the Commonwealth in engagement of future actions to be pursued under the Plan.

Secondly, I want to express my general support for the 2021 CAP's recommended response for greenhouse gas management by Pennsylvania's agriculture sector. The CAP essentially directs Pennsylvania's farmers to continue to implement and improve those conservation measures that farmers commonly recognize are environmentally effective and can feasibly be implemented or planned for implementation on their farms. While not expressly stated, the 2021 CAP recognizes that many conservation measures currently pursued by farmers provide multiple environmental benefits. More specifically, many conservation practices that improve water quality will also have meaningful and positive impacts in managing greenhouse gases.

The 2021 CAP's recommended approach for agriculture also seems to acknowledge the difficulty faced by Pennsylvania's farm families to sustain viability for their farms in today's agricultural economy and the high degree of failure that would likely occur under approaches recommending more stringent and regulatory measures on Pennsylvania farms in managing climate change effects. I and fellow Pennsylvania farmers must commonly compete with farmers outside of Pennsylvania for product sales in regional, national and even global markets. Too often we have little, if any, control over the price we receive and must accept the prices offered under the raw economic forces of supply and demand. Essentially, farmers are economically unable to pass on the additional costs to result from increased regulation to their purchasers.

Recent studies of farming operations in the Chesapeake Bay Watershed by Penn State University have shown that, despite economic challenges, many Pennsylvania farmers are willing and making an earnest effort to implement and self-finance effective conservation measures on their farms without governmental financial assistance. And we would like to do more if the economics of our farm operations would provide greater opportunity. The balanced approach recommended under the 2021 CAP provides both a realistic prospect and positive encouragement for additional engagement by farmers to reduce greenhouse gas emissions and ultimate achievement of sustained greenhouse gas reductions from Pennsylvania's agriculture sector.

And without going into detail, the 2021 CAP's approach for agriculture is very much in line with the policy objectives of climate change for agriculture outlined so far by the Biden Administration, which mainly calls for financially incentivizing farmers to reduce greenhouse gas emissions through more market-based initiatives.

I would also express my support for the recommendation offered in the 2021 CAP for implementation of a state program to provide financial assistance to farmers for replacement of lighting, refrigeration, ventilation and other fixtures in farm buildings and structures with those that are more energy efficient. I believe such a program would greatly lower energy consumption on farms (and need for generation of additional energy to meet consumption demand) with relatively modest commitment of public funds.

I do have significant concerns with the potential for governmental actions to be pursued by the Commonwealth under the 2021 CAP to impose serious economic and cost disadvantages upon Pennsylvania's agricultural producers, relative to producers outside Pennsylvania. While the 2021 CAP outlines the greenhouse gas reduction goals to be attained and generally identifies those sectors from which there will be higher expectation of greenhouse gas reduction, the CAP provides far less detail on how the reductions will be achieved by each sector.

Three of the sectors mainly targeted for greenhouse gas reductions in the 2021 CAP – electricity generation, transportation and fuel production – are sectors whose products are heavily used and consumed in farming operations. To viably operate their farms, farmers need to consume significant amounts of electricity and motor and heating fuel. And whether they are performing the task themselves or contracting others, farmers must engage in high level of transportation activities in the production and harvesting of field commodities and in the movement of agricultural supplies to and agricultural products from their farms. The concentrated levels of energy consumption and transportation tasks are major cost items for farming operations.

Extreme governmental actions that impose upon energy and transportation sectors arbitrary and unreasonable mandates for greenhouse gas reductions have a likely potential to result in huge cost increases for those sectors to remain in business. And those who rely on the energy products and transportation services provided by these sectors, such as farmers, will likely bear huge cost increases from price increases imposed by these sectors to offset their additional costs. As I mentioned earlier, agricultural producers have little meaningful ability to affect the price they receive for their products or to pass onto purchasers the additional production costs they incur.

Especially when considering the smaller size and scale of production of Pennsylvania's farms and challenges that Pennsylvania's farmers face in production efficiency (i.e. shorter growing seasons, proportionately less farmland area with optimum soils, and proportionately greater area of significantly sloped farmland) relative to farms in other regions of the county, the ability of Pennsylvania's farmers to manage their cost of production will become even more critical in future decades. Unless serious consideration is given to the economic impacts of governmental actions to energy suppliers and transportation service providers, Pennsylvania's pursuit of greenhouse gas reduction goals prescribed in the 2021 CAP could readily lead to serious increases in price of energy supplies and performance of transportation services. Because of the high degree that energy and transportation costs contribute to farmers' overall cost of production, spikes in purchase price of energy supplies and transportation services would place Pennsylvania farms in serious economic vulnerability.

The 2021 CAP also seems to encourage more aggressive pursuit of development of infrastructure for solar energy generation throughout the Commonwealth. There is potential for Pennsylvania and Pennsylvania's farmers to be benefited from solar energy development. But there is also a real risk for solar energy development to seriously conflict with productive farm management without careful consideration and assessment of impacts of size and location of proposed development projects on affected and neighboring farms. Because of relatively more beneficial land conditions, many of Pennsylvania's farms are being targeted as prime spots for solar energy development. Solar energy development must not be augmented at the sacrifice of compromising the integrity of the agricultural productivity of individual farms or the local agricultural economy. Commonwealth officials must keep in mind that once productive farmland is converted to another land use– even one can potentially provide public benefit – it is extremely difficult, if not wholly unfeasible, for that land be reconverted for farm use.

I also have concern with the degree of real benefit that Pennsylvania's pursuit and attainment of the 2021 CAP goals will provide in environmental quality relative to the additional costs and economic disadvantages the CAP would potentially impose on Pennsylvanians. Essentially Pennsylvania would be acting unilaterally to attain the 2021 CAP's prescribed goals, without assurance that other states would be working in similar fashion to attain similar goals in their states. Without this assurance, Pennsylvanians could receive little or no meaningful improvement to effects of climate change for the additional personal and economic costs incurred because of failure by other states to act in similar fashion. And Pennsylvania farmers could become subject to serious economic and cost disadvantages in competing with farmers of other states in the marketing of their farm products, as I mentioned earlier.

As with many “plans,” the success or failure of the 2021 CAP will depend on whether it can be achieved through means that minimize to the highest degree feasible imposition of onerous burdens on individuals and businesses within Pennsylvania. To ensure that does not happen, there needs to be thorough and continued evaluation of each governmental program and action to be performed pursuant to the CAP, with continued opportunity for transparency and comment by those parties who will potentially be adversely affected by that program or action.

Thank you again for the opportunity to offer comment.

Sincerely,

Luke F. Brubaker

Luke Brubaker

Comments on 2021 Climate Action Plan

As a member of the Climate Change Advisory Committee (CCAC), I appreciate the opportunity to participate in the committee meetings and provide feedback to the Pennsylvania Department of Environmental Protection (Department) on the 2021 Pennsylvania Climate Action Plan (CAP). The CAP was prepared by the Department with support from ICF and is a product of the Department -- not the CCAC. The Report is prepared to update the original Climate Change Action Plan issued in 2009. This is the fourth iteration of the CAP under the Pennsylvania Climate Change Act (Act 270 of 2008). The CAP is quite expansive and addresses a multitude of issues identified by the Department to which ICF has researched and responded. While the CCAC was regularly updated on the CAP at regularly scheduled CCAC meetings and given the opportunity to provide input and comments on the CAP, the CCAC did not directly draft nor conduct any vote on or endorsement of the final CAP.

Overreliance on energy generation sector

The CAP continues to place most of the reductions of CO2 either directly or indirectly on the existing electric generation fleet. However, the report fails to recognize the contributions that Pennsylvania electric generating units (EGUs) have already made to significantly reduce the industry's greenhouse gas (GHG) footprint. This is a critical point in what Pennsylvania has already accomplished to date in terms of GHG emissions.

Pennsylvania had 78 coal-fired and coal refuse generating units at 40 locations in 2005, with 20,475 megawatts (MW) of capacity – representing 41.5% of the state's total electric generating capacity. Today, Pennsylvania coal-fired generation has dropped to six plants. Of those plants, one is scheduled to retire by 2022 and two are switching from coal to gas over the next decade, leaving only three operating coal-fired plants. One can assume the bulk of the CO2 reductions in Pennsylvania, since 2005, have come primarily from coal-fired power plants being shut down.

There were 15 coal refuse fired plants – 6 bituminous and 9 anthracite. Of these, five facilities have been permanently retired. Several others have been operating seasonally and were at risk of closure prior to recent legislative and regulatory changes. With the loss of each coal refuse to energy plant comes an attendant loss of remediation of hundreds of thousands of tons of coal refuse each year.

From an electric generation standpoint, the CAP is proposing "amending and increasing the Alternative Energy Portfolio Standard (AEPS) to an in-state requirement of 100% by 2050 to achieve a carbon-free electricity grid." This would be accomplished by increasing Tier 1 targets and the solar carve-out, as well as including nuclear, fossil energy with carbon capture and sequestration, energy storage as eligible Tier 1 energy sources, or creating a new tier in the portfolio of options to meet the 100% target. I am please the CAP proposes to maintain the Tier 2 requirement at the current level of 10% through 2050.

What is playing out with these initiatives is a "de-facto" reregulation of Pennsylvania's electric industry. These types of out of market payments impact the PJM energy market and how generators bid and price capacity in the electric generating market. If these suggested changes are made to the AEPS, nearly all of generating capacity in Pennsylvania will be receiving subsidies from the state by 2050. This does not account for federal subsidies for wind and solar generation and any future federal subsidy for other types of generation. From a competitive electric generating market perspective, the impact of these policies create a double hit for coal and natural gas EGUs when competing with solar, wind, and nuclear generation. First, these generation sources would obtain significant subsidies from both the AEPS and federal tax credits for solar and wind. Whereas, coal and gas EGUs would be further burdened as a result of the cap and trade system charging for carbon emissions.

The CAP also fails to take into account the cost of managing both low- and high-level radioactive waste from nuclear power plants. Further, as these plants age, the cost of maintenance increases, which include the management or replacement of equipment. The solar industry has its own issues forthcoming dealing with the management of solar panels as they come to their end-of-life performance or even when there are panels being replaced in the interim for poor performance.

Overlooks the benefits of coal refuse energy and reclamation

Coal refuse-fired EGUs represent a major force in the reclamation of abandon mine land. The CAP appears to support these facilities by maintaining the AEPS Tier 2 requirement at the current level of 10% through 2050. Tier 2 resources are limited to waste coal, distributed generation systems, demand-side management, large-scale hydropower, municipal solid waste, integrated combined coal gasification technology, and generation of electricity utilizing by-products of the pulping process and wood manufacturing. The majority of Tier 2 energy comes from coal refuse energy generation. However, by including a 100% carbon free grid strategy and subsidies for competing generation sources, the result could be the loss of nearly all of this environmentally beneficial power generation from coal refuse-fired EGUs.

The CAP fails to take into account the reduction of GHG emissions from coal refuse reclamation when calculating the impact of coal refuse generation. Similar to biomass energy generation, coal refuse should be considered a "low carbon" or "carbon neutral" fuel, meaning that carbon emitted by burning the fuel does not contribute additional GHG to climate change. There are annual air and GHG emissions due to the very existence of abandoned coal refuse piles in Pennsylvania. Absent the coal refuse reclamation to energy industry, air pollutants and GHG emissions from coal refuse piles will continue to hinder progress toward improvements in air quality and climate change for hundreds of years. Openly smoldering or burning coal refuse in stationary piles and ongoing "low temperature oxidation" of exposed coal piles create uncontrolled air emissions, including GHG emissions. Additionally, by providing the Commonwealth with land remediation and water quality improvements by reclaiming these previously polluted and barren sites, they begin to act as carbon sinks through establishing vegetation and wildlife habitats.

In the recently adopted CO2 Budget Trading Program (RGGI), the Department set aside 12.8 million CO2 allowances annually for this industry to recognize "waste coal-fired units provide an environmental benefit of reducing the amount of waste coal piles in this Commonwealth. Reducing waste coal piles is a significant environmental issue in this Commonwealth, because waste coal piles cause air and water pollution, as well as safety concerns." Additionally, by precluding and extinguishing abandoned coal refuse pile fires created by spontaneous combustion or human interface, these facilities prevent uncontrolled emissions which contain significantly higher GHG and other emissions.

The strategy to "Increase Land and Forest Management for Natural Sequestration" includes additional conversion of abandoned mined lands but fails to recognize the benefits of the coal refuse reclamation to energy industry in this strategy. According to a 2019 study by Econsult Solutions, the industry can reclaim up to 240 acres of abandoned mine lands at its peak operations by removing harmful coal refuse piles and restoring natural vegetation to historic mining lands. While it is true "reforestation is not always an option, replanting native vegetation of many varieties can sequester more carbon than bare mine lands." A lack of funding for was cited as a challenge to this strategy, but the coal refuse reclamation to energy industry invests significant private funds annually to replanting and reforestation efforts on abandoned mine lands.

It also needs to be recognized that unreclaimed coal refuse sites are major source of water pollution from sediment laden runoff and mine drainage. In the 2013 Pennsylvania Climate Assessment Update, Penn State

University was projecting wetter periods with increased runoff. From a climate change perspective, if, as projected, there are increased in more intense precipitation events, that will mean more silt and water pollution will come from these sites. For the unreclaimed abandoned coal refuse sites, this would mean higher sediment laden runoff and increase in mine drainage from these sites. Yet, while the Department discusses in overview form the need for stormwater management, it ignores the benefits of coal refuse reclamation to energy, thereby moving to a future without the tools available to reclaim and ameliorate water quality from abandoned mine lands polluted by coal refuse.

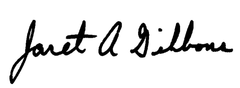
Coal refuse should be modeled and reported as a separate fuel type for energy generation

The CAP breaks out emissions from the electricity generation sector by fuel type, including coal, natural gas, nuclear, renewables, and other. I appreciate the Department clarifying that throughout the CAP the fuel type "Coal" includes "electricity generation from waste coal"; however, I believe that this is not the appropriate fuel type classification. Ideally, waste coal energy generation should be modeled as its own separate fuel type. Alternatively, it would more appropriately be included in the "Other" fuel type, which "includes electricity generation from waste-to-energy and landfill gas facilities" as coal refuse is a waste energy fuel that is more akin to municipal waste than coal.

Coal refuse energy generation has significant differences from traditional coal energy generation, both in terms of the design and operation of the generation technologies utilized at the facilities, as well as the fuel itself. Coal refuse energy facilities utilize a relatively newer and evolving technology where coal refuse is used as fuel in circulating fluidized bed (CFB) boilers that combust it with limestone injection to control air emissions and generate electricity as a viable and environmentally acceptable means to remove polluting coal refuse piles. The resulting highly alkaline ash differs from traditional coal ash and is beneficially used for reclaiming historic mine land sites. These facilities are some of the lowest emitters of air pollutants, including mercury and filterable particulate matter.

Coal refuse is not "Coal" but rather a waste product of the mining process that often contains a variety of substances including rock, clay and other organic and inorganic material. In Pennsylvania, our waste coal is primarily anthracite culm and bituminous gob. The U.S. Energy Information Administration (EIA) defines coal as, "readily combustible black or brownish-black rock whose composition, including inherent moisture, consists of more than 50 percent by weight and more than 70 percent by volume of carbonaceous material." Coal refuse does not meet this definition, but is separately defined as, "a byproduct of previous coal processing operations… composed of mixed coal, soil, and rock (mine waste)." It frequently has high ash or sulfur content making it unable to meet quality and heating characteristics of the boiler design at a coal power plant. The fact that it does not meet the technical characteristic of coal for use in energy production is why it is discarded as waste, thereby making its fuel type classification as "Coal" both unreasonable and inaccurate.

Respectfully submitted,



Jaret A. Gibbons
CCAC Member

COMMENTS ON 2021 CLIMATE CHANGE ACTION PLAN
PREPARED BY PA DEPARTMENT OF ENVIRONMENTAL PROTECTION
PURSUANT TO ACT 70 OF 2008

SUBMITTED BY PATRICK HENDERSON
Member – Climate Change Advisory Committee

July 2021

Too often, those positioned to implement sensible emission-reduction strategies are instead more fixated on compelling others to acknowledge the urgency and nobility of their cause.

Climate change is the McCarthyism of our time.

INTRODUCTION

As a member of the Climate Change Advisory Committee (CCAC), I appreciate the opportunity to share these comments and response to the final 2021 Climate Change Action Plan (Action Plan or CAP) of the Department of Environmental Protection (Department or PA DEP).

The Department's program staff are to be commended for their diligence in assisting the CCAC in reviewing prior drafts of this Action Plan, along with associated documents such as the Climate Impacts Assessment and Greenhouse Gas Inventory, and the facilitation of additional information to the CCAC during its development.

Despite the significant and commendable effort which went into preparing the Action Plan, there are several important areas where I diverge with the Action Plan's conclusions and recommendations. The following reflect my personal comments as a member of the CCAC; they do not reflect, nor have they been reviewed and approved, by my employer or anyone else.

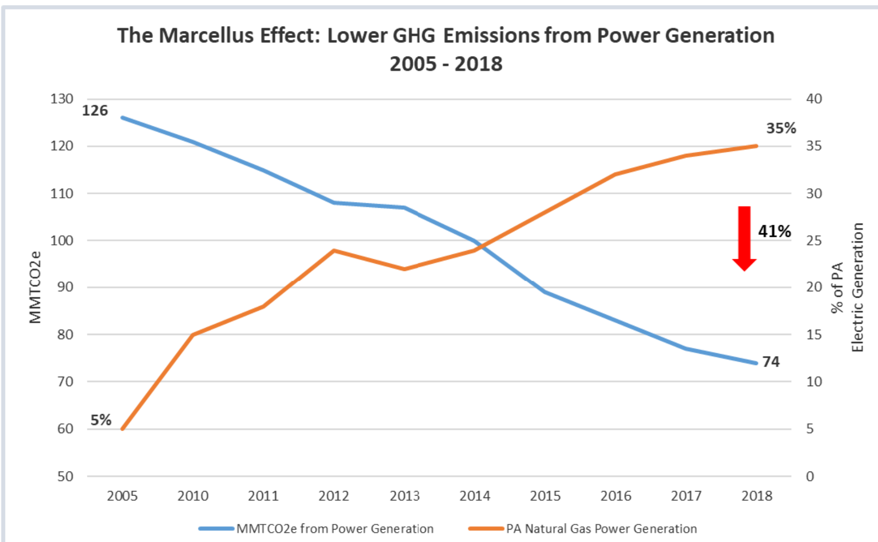
PENNSYLVANIA'S CURRENT GREENHOUSE GAS EMISSION PROGRESS

Notably lacking from the CAP is a discussion on the progress that Pennsylvania has made over the past decade plus in reducing its emissions related to climate change. The CAP serves as the primary forward-facing document for the Department's efforts related to climate change, and it befuddles me that the Department knowingly shies away from informing readers that Pennsylvania has made tremendous progress in reducing emissions to date. I urged the Department to do so in the last iteration of the CAP, but this recommendation is again – mostly – ignored.[1]

[1] Scant attention is paid to historical reductions of GHG emissions in PA on pages 10 – 11 of the report. However, a reader of this report would never know, for example, that Pennsylvania has reduced its carbon dioxide emissions from power generation by perhaps more than any other state in the nation and serves as the second-largest exporter of electricity in the nation, with significant electricity exported to power New England and Mid-Atlantic states that jettisoned their own power generation in response to the RGGI.

Recognizing the progress made to date does not equate to dismissing the need for additional progress. Rather, it informs readers and policymakers that will evaluate the recommendations of the CAP and allows for proper gauging of government-mandated steps compared to market-induced progress. It is notable that the vast majority of the progress realized is market-driven through the citing of new natural gas electric generation facilities. It is also worth recognizing that state policies that help create a competitive electric market, and which shifted the risk of capital investment for power generation from ratepayers to the private market without micromanaging the Commonwealth's electricity portfolio, are significant contributors to this progress.

In Pennsylvania (and as noted in passing in the CAP), the power generation sector has seen a significant increase in the use of natural gas for electricity. There is a direct correlation between the use of natural gas, spurred by the development of the Marcellus Shale and other unconventional natural gas resources, and the decline in carbon dioxide emissions from the sector, as illustrated in this chart below[2]:



LACK OF CLEARLY UNDERSTOOD BENEFITS FOR PENNSYLVANIANS

While the Action Plan includes sweeping new recommendations, including transformation of Pennsylvania's competitive electric generation markets to a command-and-control, centrally-administered portfolio mandate and the discontinuation of coal and natural gas electric generation, there are no clearly defined benefits to be achieved and delivered to the citizens of Pennsylvania if these recommendations are implemented.

[2] Source: U.S. Energy Information Administration

To the extent that the Action Plan includes benefits, it is in the context of specific recommendations that, if implemented, may lead to a quantifiable emission reduction. However, despite ominous warnings that climate change will lead to draconian outcomes if unchecked,[3] the Action Plan fails to include tangible and specific benefits that Pennsylvanians will see should these recommendations be implemented, such as:

- Less-than-projected average temperature increases
- Less saltwater encroachment up the Delaware River estuary
- Maintained or increased water levels in Lake Erie
- Less frequent heavy rain events
- Less severe and fewer flooding events
- Less severe heat waves
- Lower health care costs, including averted premature deaths
- Lower-than-projected rising sea levels
- Fewer-than-projected invasive species

Pennsylvanians are expected to accept that 'less is better' and therefore worthy of the economic costs, sacrifices and impositions to be borne should these recommendations be implemented. While the Action Plan goes to extensive lengths to quantify the costs of climate change to date, as well as future impacts under a business-as-usual scenario, the lack of tangible and specific benefits for Pennsylvanians under this plan is conspicuous and undermines the merits of pursuing many of the suggested policies.

Moreover, to the extent that the overriding benefit of this suite of recommendations is to keep global temperature increases to below the two degree Celsius threshold asserted as necessary to avoid the most dire of consequences from a changing climate, it is imperative for the public and policymakers to understand the following: even proponents acknowledge that this benefit can only be achieved if *"All states achieved similar greenhouse gas reduction targets, and other nations met comparable goals."*[4]

THE FATAL FLAW

The Department and its consultant have evaluated a variety of recommended policies to gauge their cost effectiveness in reducing greenhouse gas emissions within the Commonwealth. The Department has acknowledged that none of these policies have been evaluated to gauge their impact on displacing, or leading to increased, greenhouse gas emissions in other states.

Given that climate change is a global challenge, and that greenhouse gases such as carbon dioxide and methane do not present or pose specific local air quality or respiratory issues, it

[3] Page viii of the CAP warns of higher average temperatures, increased heat waves, saltwater encroachment up the Delaware River estuary, increased droughts, heavier, more severe rain events and other impacts
[4] Page 14 of 2019 Climate Change Action Plan

only makes sense to understand whether a particular policy will lead to a net reduction of greenhouse gas emissions.

The Department's failure to do so renders the recommendations contained in the CAP untested in this regard, and therefore not worthy of implementation because there is no assurance that they will actually achieve a net reduction of greenhouse gas emissions.

SOMETIMES IT RAINS; SOMETIMES IT DOESN'T

While this heading is offered somewhat tongue in cheek – recognition of the impact human activity can have on our environment is important and impacts ought to always be minimized when feasible – it is not an exaggeration to suggest that, in some quarters, nearly every severe or extreme weather event, including the *lack of* an event (such as a drought), seems attributable to climate change. It is akin to proving a negative: demonstrate that some adverse event is *not* the result of climate change. This presents a conundrum which proponents of radical policies have cleverly mastered, too often abetted by public policymakers who ought to know better: blame floods, wildfires, extreme heat, extreme cold and other weather-related events that will cause countless, avoidable deaths on climate change.

> *"And we're, like, the world is gonna end in twelve years if we don't address climate change…and your biggest issue is how are we gonna pay for it?"*
>
> **~ U.S. Rep. Alexandria Ocasio-Cortez (D-NY), Lead Architect of Congressional Climate Change Policy - #MLKNow 2019 Event – Jan. 21, 2019**
>
> **UDATE: The world will now end in ten years.**

Without discounting the need to continue to improve upon the success to date, PA DEP should acknowledge that the human race has made significant progress to minimize weather-related deaths. According to the Reason Foundation,[5] aggregate mortality attributable to extreme weather events has declined by 90% since 1920. Additional analysis concludes:

- Deaths and death rates from droughts, which were responsible for approximately 60% of cumulative deaths due to extreme weather events from 1900–2010, are more than 99.9% lower than in the 1920s;
- Deaths and death rates for floods, responsible for over 30% of cumulative extreme weather deaths, have declined by over 98% since the 1930s;
- Deaths and death rates for storms (i.e. hurricanes, cyclones, tornados, typhoons), responsible for around 7% of extreme weather deaths from 1900–2008, declined by more than 55% since the 1970s.

Under any circumstance, people are significantly better protected today from the impacts of extreme weather events than at any time in recorded history. Much of this protection is rooted

[5] Wealth and Safety: The Amazing Decline in Deaths from Extreme Weather in an Era of Global Warming, 1900–2010: Indur Goklany – The Reason Foundation – September 2011

in progress attributable to affordable, domestic and abundant energy resources – energy resources which are now targeted for elimination under this CAP's recommended policies.

PA DEP's ROLE IS TO PROTECT THE ENVIRONMENT – NOT DICTATE ENERGY CHOICES

The role of any environmental regulatory agency is to protect the environment and by extension public health in accordance with the statutes and regulations which lay out their specific obligations. However, too often agencies and those who run them have veered from this charge and instead used the tools at their disposal to advance their vision of the world. Nowhere is this more apparent than in a regulatory agency using its vast reach to dictate energy portfolios or to advocate for or against a specific energy resource.

PA DEP has in recent years sought to oppose the extraction, development and use of fossil fuels, while using its public platform to champion its preferred sources of energy such as wind, solar and other alternative energy resources. The CAP plan provides numerous examples of this, where the Department is focused less on environmental outcomes and more on dictating how to get there. Proposals to mandate that Pennsylvania expand its Tier 1 electric generation portfolio to 100%, leaving no room for traditional sources such as coal or natural gas, is but one example.

PA DEP is even more direct in articulating its opposition to fossil fuel development. For example, in materials prepared for the CCAC outlining the Impacts Assessment and CAP at its December 2020 meeting, the Department touted efforts to "*potentially displace hydraulically fractured or conventional gas*". Why?

This is highly inappropriate. To be clear, the Department's role should be to ensure that any energy resources which are developed are done in a manner that protects public health and the environment; not to dictate which resources are actually developed. Publicly cheerleading[6] for the success of certain preferred energy sources calls into question the objectivity and fairness in the treatment of other energy sources.

"CLEAN" ENERGY

The CAP uses the term "clean energy" nearly 60 times throughout its narrative, with references to "clean energy" jobs,[7] electric generation sources, and taxpayer funding. This term is a

[6] Since 2015, the Department has devoted significant time, energy and financial resources to advocating for solar energy, including contracting with a Harrisburg anti-fossil fuel lobbying organization funded in part by a Pittsburgh-based anti-immigrant foundation to launch a solar deployment initiative. From 2015 to present, the Department has issued over 50 press releases touting the benefits of solar energy, and zero press releases touting the benefits of natural gas or coal.

[7] The definition of "clean energy" jobs is, to put it mildly, overly generous. The Department's own report categorizes 50% of clean energy jobs as coming from the traditional and high-efficiency HVAC sector: 2020 PA Clean Energy Employment Report –

misnomer, unfairly and inaccurately implying that anything which does not meet this narrow definition is "dirty" energy.

This designation ostensibly refers to the fact that some electric generation sources have no or minimal direct emissions at the point of generation. This narrow definition conveniently ignores the significant fossil fuel energy needed to construct or transport the "clean energy" generation components, including extracting through mining processes the rare earth minerals needed for many of these alternative energy sources. It also ignores that nearly all "clean energy" generation sources must be sufficiently backed up by traditional electric generation sources, typically coal, natural gas or nuclear.

Toxic rare earth mineral sludge lake, Inner Mongolia. *Credit: Liam Young/Unknown Fields. Published* www.bbc.com *April 2, 2015*

Ironically, during a time when anti-fossil fuel advocates insist that fossil fuels be critiqued for impacts throughout their life cycle (extraction to disposal), they reject the application of this very principle to those energy sources they seek to assert are "clean".

TRANSPARENCY OF CONSULTING CONTRACT

While claims of transparency from PA DEP and the Administration have been a consistent theme over the years, the Department's handling of its consulting contract to prepare this report does not comport with the spirit of these public assurances. Like prior CAP reports, the Department commissioned ICF Incorporated from Fairfax, Virginia to help prepare this latest CAP update. Despite legal requirements that all contracts also be posted and available on the Pennsylvania Treasury Department's website, the contract[8] awarded to ICF Incorporated is not available to the public. Rather, the Department executed a "Purchase Order" (# 4300664666) for ICF Incorporated's services related to CAP under a generic contract (# 4400007410) awarded to ICF Incorporated in 2012 by the state's Department of General Services. This generic contract, available online purportedly to comply with the law, lists no specific tasks or services to be performed by ICF Incorporated, nor does it reflect any expenditure of Pennsylvania

https://files.dep.state.pa.us/Energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/2020EnergyReport/2020_PACEIR_FINAL_1.1.pdf

[8] The agency may argue that, legally, it issued a Purchase Order, not a contract to ICF, and therefore is exempt from the public disclosure requirement. Any such assertion would be widely regarded by the public as mere semantics.

taxpayer money. It generally reflects that ICF Incorporated is a recognized contractor to be called upon in the future for the delivery of specific tasks and services – to be delineated in future "purchase orders". Again, these purchase orders are not publicly available.

To wit, any member of the public which sought to utilize the Pennsylvania Treasury Department's contracts e-Library would never have a clue that ICF Incorporated was receiving $399,990 to perform services related to the preparation of the CAP Update. Going forward, the Department should pledge to submit for public disclosure to the State Treasurer all Purchase Orders it enters into for services. It should also commit to posting these contracts and purchase orders – along with a clear explanation in layman's terms as to what they encompass – on its own publicly available website.[9]

This may be viewed as some by 'inside baseball' and by others as gratuitous commentary irrelevant to the topic at hand. Yet absent raising these concerns here, I don't know of a forum or venue in which to illustrate them. In addition, the associated costs are worthy of public disclosure because doing so is necessary for the public and policymakers to evaluate whether the expenditure of these funds is appropriate and proportionate to the services rendered.

REPEAL ACT 70

Act 70 should be repealed by the General Assembly because developing a CAP is an expensive, time-consuming process that has, to date, resulted in no meaningful – if any – cumulative greenhouse gas emission reductions for Pennsylvania.

DEP seems more fixated on initiating the *next* CAP as soon as one is done, rather than seeking to implement the recommended policies and initiatives of the prior plan. While this may be fortuitous in my own personal view, because I view many of the recommendations as detrimental to our Commonwealth, it nonetheless calls into question: what is the purpose of the plan? If any steps are taken, they are often efforts which would have transpired regardless of the existence or recommendation of the CAP – but are then credited in part to the CAP to demonstrate its value or contribution to the effort. Often, at least in this advisory committee member's view, the CAP and accompanying recommendations are used as political cover to advance tangentially related policies, such as taxpayer subsidization of renewable energy or opposition to fossil fuel development and use, under the guise of addressing climate change.

---

[9] Worth noting: PA DEP issued another Purchase Order (# 4300636995) in the amount of $375,000 to ICF Incorporated to perform an analysis of a proposed rulemaking petition pertaining to greenhouse gas cap and trade, under Contract # 4400011024. Neither the Purchase Order nor a description of services to be provided – nor a later amendment to expand the scope and amount of said Purchase Order to include modeling of Governor Wolf's proposed Regional Greenhouse Gas Initiative (RGGI) regulation – is publicly disclosed or available. An additional contract valued at up to $10 Million awarded by PA DEP to the Delta Institute to advise the Department on how to spend RGGI tax revenue, while publicly available on DGS's website, fails to disclose any scope of services or contracted deliverables, other than the amount and the timeframe of the nearly 8,000 year contract through December 31, 9999 (Contract # 4400023719)

This recommendation – which admittedly is not politically feasible – is not meant to suggest that meaningful dialogue on climate change is unwarranted. It is meant to suggest that the current approach simply is not an effective way of doing so.

I also question the value with which some in the Department hold the viewpoint and input of the CCAC. To be clear, the committee is ably run and has been for years by outstanding committee chairs and vice chairs. And the program staff of the Department which interacts with the CCAC has, as always, comported itself with professionalism while providing timely, informed and knowledgeable assistance to the CCAC. The citizens of Pennsylvania are fortunate to have them working on our behalf.

The members of the committee devote significant personal time from their daily jobs and personal obligations to attend and participate in the meetings, and countless hours of deliberation and input is provided outside of the regular meeting schedule. We knew this was the bargain when we signed up to volunteer for these positions.

Yet, I would be remiss, and perhaps derelict in my duties, to not observe that senior management of the Department does not make the same investment. Any input to senior management from the CCAC seems limited to second-hand relaying of discussions by department program staff or reading of letters such as this. To illustrate this frustration, neither the Secretary nor a member of the DEP Executive office has attended a meeting of the CCAC over the past six years.[10] Despite multiple and repeated protestations that climate change is the single most important threat posed by our nation and environment today, they have never seen fit to receive first-hand input or reaction from those citizen-volunteers who serve on the CCAC.

Conclusion

These thoughts, comments, observations and recommendations are mine and mine alone. I appreciate the time anyone has taken to read them.

[10] I note for the record that the DEP Policy Office is regularly engaged with the CCAC. That engagement is noted and appreciated.

Gary L Merritt
1054 West Areba Ave
Hershey, Pa 17033

July 22, 2021

David Althoff, Jr.
Director
Energy Program Office
Pa Department of Environmental Protection
Rachel Carson State Office Building
400 Market Street
Harrisburg, PA 17101

and

Lindsay A. Byron, P.G.
Environmental Group Manager
Energy Program Office
Pa Department of Environmental Protection
Rachel Carson State Office Building
400 Market Street
Harrisburg, PA 17101

Re: Comments
Pennsylvania Climate Action Plan of 2021
June 2021

Dear David and Lindsay:

The Pennsylvania Climate Action Plan of 2021 ("Climate Action Plan") fails to consider all factors and needs to more fully vetted with the analysis being performed controlled by the Pennsylvania Department of Environmental Protection ("Department") and its Consultant ("ICF").

The Climate Action Plan promotes the benefits of certain industries without considering the negative economic impacts on those industries and related industries. In addition, the economic impacts should also consider impacts on the local tax base, education, and health care. Further, the Climate Action Plan only discusses the perceived negatives of the Department and ICF's unfavored industries and fails to discuss the benefits of their unfavored industries. As a result, the Climate Action Plan reads as a promotional advertisement for their favored industries such as solar energy. Rather than questioning specific areas or topics, the intent is to highlight areas where additional analysis and reviews are deemed to be needed. These areas are:

Net Zero Decarbonization:

The Climate Action Plan fails to clearly define "net zero decarbonization". Is this term solely for the Electric Grid or does it include the non-EGU Industrial Manufacturing Sectors?

The term "net-zero" implies that there will be a need for carbon offsets; however, the Climate Action Plan fails to adequately address. Will there be offsets? How do you track and/or certify any offsets and/or carbon credits? The Climate Action Plan fails to mention or include the self-remediating efforts of various industries.

Further, the Climate Action Plan looks at certain industries in a vacuum rather than looking at the entirety of the industry. For example, the waste coal to energy industry is part of the reclamation process in Pennsylvania and therefore, the overall long-term benefits are substantial when considering that these facilities are reclaiming legacy coal mining areas while producing reliable energy. Further, this industry has substantial environmental benefits which have long been recognized in the Commonwealth.

Electrification of the Grid:

The Climate Action Plan argues for a greater electrification of the grid including but not limited to, electric cars and other vehicles, through the use of electrical furnaces and boilers by the non-EGU Industrial Sector and pushing for the electrification of the homes. However, the Climate Action Plan fails to address and/or provide projections for the increase electric consumption together with how the Commonwealth will meet this increase demand.

The Climate Action Plan should address how the Commonwealth intends to meet future energy demands especially when the Climate Action Plan pursues objectives that would eliminate reliable sources of energy such as the coal industry and the current state of the nuclear energy when considering general market factors. The Climate Action Plan should address how the Commonwealth intends to provide sufficient electric to meet the rising demand in electricity while at the same time, the Commonwealth is pursuing regulatory actions together with market factors that is resulting in a decrease in the supply of reliable electricity. Pennsylvania has a great resource with a diverse portfolio of energy sources, which it should harness rather than play favorites. The potential economic and social costs to the ratepayers, taxpayers, and communities should be included in the Climate Action Plan.

Paris Accords:

With regards to the various signatories to the Paris Accords as it relates to Climate Change, has any determination been made that the required solar, wind and battery storage facilities can be produced and installed within the agreed to time frames? While one projects that the cost of solar, wind and battery storage will decrease; however, if demand increases in order to meet the requirements of the Paris Accords, it seems that price and costs will increase, potentially significantly. As with any commodity and/or good, when demand increases, typically the price and costs increase as demand exceeds supply.

Role of Rare Earth

The push for renewable energy (especially solar and wind) and the "economics" in the push towards decarbonization of the grid is completely ignorant and fails to consider the potential demand of rare earth minerals. Further, the Climate Action Plan overlooks, albeit intentionally, the social and environmental costs to mine and produce rare earth minerals.

To meet greenhouse gas emission reduction targets under the Paris Accords, it will require an accelerated ramping up of renewable energy production. This "accelerated ramping" requires the global production of rare earth minerals (especially neodymium, terbium, indium, dysprosium, and praseodymium) will need to grow by a 12-fold factor by 2050. (This does not include the need for these same rare earths for other purposes.)

This, today, the current global supply of critical rare earth metals is insufficient to meet the demand resulting from the transition to renewable energy systems!

The critical demands for these metals will have a significant impact on electronics, on the auto industry, and more importantly on our defense industry and on our national defense raises serious concerns about the overall strategy to use renewable energy even in the manufacturing industry.

While recognizing the above, what is not considered is the supply chain GHG emissions tied to the mining, processing, and production of these metals. Further, this does not include the environmental impacts of the production. China represents 80% of the production and 95% of the refining.

By pushing and not considering this, the impact strengthens China economic engine while reducing our ability to compete and creating concerns regarding our national defense. It also creates other social, economic, and environmental issues and/or harms that significantly outweigh the perceived harms of carbon producing sources of energy.

Tax Incentives:

The solar industry is being driven by the various incentives such as tax credits and other subsidies. What is intriguing is the effort placed on providing tax credit incentives coupled with renewable energy credits creating an uneven playing field. The claims that renewable energy can compete with fossil fuel generation is misleading. Without these two elements, solar power loses its momentum.

Without the Federal Tax Credit subsidy and renewable energy credits, the ability to compete is limited by the cost per MW generated.

The Climate Action Plan fails to address the societal and economic harm to ratepayers and taxpayers in Pennsylvania as a result of the various Federal incentives. Instead, the Climate Action Plan assumes that Pennsylvania taxpayers and ratepayers will be willing to absorb the heavy burden of promoting certain renewable energy sources when view in light of jobs losses and unemployment; reduction in tax base revenues to local communities and the local school districts (both in property taxes and wages taxes.

Biofuels:

The push to use biofuels as an energy source leads to a slippery slope. As biofuel projects develop (even if sustainable), the impact of converting these agricultural lands to producing biofuel crops place a greater impact on agricultural production to provide basic food production. This is especially important when some farms are leasing their property to solar farms, which results in less crops. With the population continually growing, we will need to produce more food to meet the demand of the population. However, with the incentives set forth above, farmers are now converting their farmland into biofuel projects and/or solar farms. This could result in food shortages and other social, economic and/or environmental harms that the Climate Action Plan fails to even acknowledge.

Solar and Wind Projects:

The Climate Action Plan promotes the expansion of solar and wind projects. Instead of having these projects being developed on forested lands and agricultural lands (as we are doing now), the Commonwealth should actively seek and promote these types of projects on brownfields and grayfields (especially on mine lands). The demand for biofuels and converting other agricultural lands to solar may have the unwanted reaction of declining food productions.

Further, the Commonwealth should be proactive in enacting legislation that prohibits local municipalities from placing restrictions on these types of projects. Unfortunately, and for example, developers of wind projects are constantly facing challenges at the local level and projects are unable to proceed as a result of being unable to obtain permits and/or objections from the municipality.

The Climate Action Plan suggests that these types of projects will be developed without any resistance from local governments. However, developers face resistance on many levels which make these types of projects costly and undesirable for developers. By focusing on brownfields and grayfields, the Commonwealth could enact legislation that these projects are permitted in those areas; thus, removing the risks for developers associated with the permitting process with local governments.

Wind Turbine and Solar Waste:

There is an obvious rush to expand solar and wind power generation without considering the harms of this industry. This rush to expand is short-sighted. What are the long-term impacts of managing these projects when these projects pass their useful life? What is the plan to dispose of solar panels, wind turbines, and/or electric cars? The Climate Action Plan fails to address how the waste produced from these projects will be addressed and thus, it fails to consider the adverse environment, social and economic harm associated with the waste and disposal of these projects after their useful life as ceased.

Additionally, the Climate Action Plan promotes solar and wind energy which does not create the same amount of energy as other sources. As a result, higher producing facilities are going off-line and/or decommissioning and being replaced with lower producing facilities such solar and wind facilities. For example, Three Mile Island nuclear power plant is being decommission. Solar and wind is unable to fill the void created by the decommissioning of Three Mile Island. Further, even assuming that solar and wind could make up for the loss of energy produced by such a nuclear facility, 1000s of acres of forest, farm land and other viable land would have to be converted from viable agricultural and/or forest land to solar and wind farms. This would result in significant costs to society.

Recycling:

The area of recycling, especially of plastics needs to be more closely examine and incentives provided! This is an area where Europe and some Asian Countries are leading the way with the technology being developed. There are several German Companies deeply involved in recycling of plastics and other wastes.

Waste Coal Facilities:

The Climate Action Plan improperly lumps waste coal facilities in with coal generating facilities. Further, the Climate Action Plan assumes that these facilities will no longer be operating in 2050; especially the waste coal plants. The waste coal plants may last longer pending the availability of coal refuse within an economic haul distance. The Commonwealth, several environmental associations, and river basin commissions have recognized the importance of this industry in reclaiming waste coal, culm and/or gob from the lands of the Commonwealth and returning these lands to a productive use and improving water quality. Pennsylvania's $15+ Billion Dollar AML problem will need help to reclaim these lands as the coal mining industry continues its consolidation and shrinkage due to the elimination of the steam and thermal coal markets.

Fossil Fuel:

Rather than eliminating fossil fuels (coal, gas, and oil) we need to go back to the development phase and look to pyrolysis to capture the carbon for manufacturing and to carbon sequestration purposes, while producing ammonia and hydrogen as the energy source.

Pennsylvania should embrace its diverse energy portfolio and its ability to be a net exporter of electricity. Pennsylvania has great resources. Communities depend on industries especially in the coal region. In addition to government regulation on the coal industry, certain banking and insurance companies have adopted policies not to loan and/or insure coal companies. In addition, a certain steel company recently announced plans to be net-zero carbon by 2050. Unfortunately, these policies and government regulation will have a substantial and devastating impact on certain, already distressed communities which rely upon the coal industry for jobs, tax revenue, and other daily functions. The Commonwealth should develop mechanisms for these industries to continue to prosper rather than trying to eliminate fossil fuels for other Department favored industries.

I would hope that future Pennsylvania Climate Action Plans look at all factors rather than limiting the factors being presented to justify the Department's Plan. Even with perceived favored industries such as solar and wind, there are negative social, economic, and environmental effects that at a minimum should be presented. These negatives factors should be part of the analyzed rather than simply excluded.

The Department has acknowledged in conversation and discussions some of these negative factors but should address them as part of future climate action plans!

Market Failures and Job Creation:

The Climate Action Plan fails to consider market factors and projections, which results in grossly inaccurate analysis. For example, the Climate Action Plan discusses the use of nuclear energy as a future source of energy. However, as we have seen with Three Mile Island and other facilities, these facilities are unable to compete with the low electric prices and the abundance of natural gas in Pennsylvania. In order to maintain the levels as set forth in the Climate Action Plan, this industry would require subsidies and/or other governmental assistance. The same can be said of the coal generation industry, where various facilities have been decommissioned and/or converted to natural gas facilities. The coal generation industry facing stricter and costly government regulations are unable to compete with natural gas and those government propped up industries like the solar and wind turbine industries.

Further, the Climate Action Plan discusses the anticipated increase of jobs as a result of the creation of solar farms and wind turbines. There may be short term jobs created; however, the Climate Action Plan fails to set forth the total impact of this transition to renewable sources of energy. For example, we are replacing large facilities with roughly 50 employees with a solar farm that has very few, if any, working on a daily basis. Also, the Climate Action Plans fails to address the loss of significant jobs in supporting industries that will also be adversely impacted. Recognizing that Environmental Justices Communities are defined by economic conditions, the impact of the proposal does not adequately assess the impact on local communities and potentially taking areas where the economic conditions presently are not considered Environmental Justice Areas to making them Environmental Justice Areas

Summary

While the Climate Change Action Plan provides the Administration directions to address the GHG Issue, it needs to provide a path forward for the following areas:

- The economic impacts related to the mining industry both in terms of employment and lost income to sustain the AML Reclamation Program; to provide similar good paying jobs that are being lost (not just job training) but jobs!
- The economic impacts of a specific industry (power generation) should not be limited to it but should include an economic analysis of the impacts on all the related industries and support industries.
- The economic impact on the local area, in terms of tax base, education, and health care.
- Programs related to waste management and recycling
- Programs to plug abandoned oil and gas wells
- Programs to support the environmental clean up of the abandon coal mine lands programs.
- Programs supporting Carbon Capture, Utilization, and Sequestration
- Insuring that new Environmental Justices Areas are not created!

We also support the recognition provided to the waste coal industry that while it has CO_2 emissions, its reclamation and remediation efforts are important providing environmental improvements and ultimately creating carbons sinks.

Thank you for the opportunity to provide comments and observations regarding the 2021 Climate Action Plan.

Sincerely,

Gary L Merritt