Pennsylvania
Climate Action Plan Update

Pennsylvania
Department of
Environmental Protection

2024

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Climate Action Plan Update

2024

Strategies for governments, businesses, industries, community leaders, and all Pennsylvanians

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Contents

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This update is a report 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 (CAP) regularly. The Pennsylvania Climate Change Advisory Committee provided input and feedback to DEP and its supporting consultant, ICF Inc, for the preparation of this assessment. The Climate Change Advisory Committee has 18 appointed members plus three ex officio members. The 2024 CAP is the sixth iteration of the Pennsylvania CAP and builds on the previous action plans. This report and the analyses contained in were led by the Pennsylvania DEP with support from ICF Inc., Penn State University, InClime Inc., and Inch and Meter, P.C. DEP also developed the legislative recommendations included within this report. All opinions, views, and recommendations expressed in this report do not reflect those of ICF Inc., Penn State University, InClime Inc., or Inch and Meter, P.C.

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Executive Summary

Climate change presents unprecedented challenges to the Commonwealth of Pennsylvania. The current impacts and future risks of climate change require swift and collaborative action to prevent the worst impacts from becoming a reality. The DEP is leading climate action for the Commonwealth and its citizens by working to better understand and communicate the risks of climate change, mitigate its causes, and adapt to its impacts to ensure the wellbeing of all Pennsylvanians. The 2024 Pennsylvania Climate Action Plan (CAP) describes climate risks and opportunities for the Commonwealth and lays out achievable strategies for Pennsylvania to reach its climate targets for greenhouse gas (GHG) emission reduction and climate adaptation.

Addressing climate change in Pennsylvania is not a new effort. Pennsylvania established its first statewide policy on climate change in the Pennsylvania Climate Change Act of 2008 (Act 70), which requires DEP to compile an annual GHG inventory, develop a voluntary GHG registry, and develop a CAP and climate impacts assessment to be updated regularly. Act 70 also establishes the Climate Change Advisory Committee (CCAC) to advise DEP during CAP and Climate Impacts Assessment (CIA) development. Working with the CCAC, DEP has issued several climate action plans and impacts assessments over the past 16 years and this most recent CAP is the 6th that DEP has developed. Since passing Act 70, several executive orders and state legislative actions have been passed to promote energy efficiency measures, accelerate renewable and clean energy, protect the environment, and integrate environmental justice (EJ) considerations into policy.

The Commonwealth has committed to pursuing three key GHG reduction targets:

- Collectively reducing net GHG emissions at least 26-28% by 2025 compared to 2005 levels;
- Collectively reducing net GHG emissions at least 50-52% by 2030 compared to 2005 levels; and
- Collectively achieving overall net zero GHG emissions as soon as practicable, and no later than 2050.

These targets were established through a 2019 executive order issued by Governor Tom Wolf that initially 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. Also, in 2019, Pennsylvania joined the US Climate Alliance, a bipartisan coalition of governors aiming to advance high-impact climate actions and aligned with their more ambitious GHG reduction targets.

This CAP builds on previous CAPs and creates an even bolder vision for Pennsylvania by:

- Setting more ambitious climate targets for GHG emission reductions and climate adaptation;
- Providing greater emphasis on addressing climate impacts to and opportunities in Pennsylvania's EJ areas; and

Recent Pennsylvania Climate Wins

- Created the PA Climate Network for partnership, communications, and education.
- Updated the Environmental Justice Policy and expanded the Office of Environmental Justice.
- Won federal funds for Hydrogen Hubs to create clean energy jobs and expand clean energy.
- Plugged orphaned wells to reduce emissions.
- Financed an energy efficiency mechanism through the Guaranteed Energy Savings Act, among other financing mechanisms.
- Created eight conservation landscapes to foster community engagement in sustainability, conservation, and recreation projects.
- Updated the Citizen Hazard Preparedness Guide.
- $396 million grant for the Reducing Industrial Sector Emissions in Pennsylvania (RISE PA) project.

- Detailing tangible implementation steps and DEP's legislative recommendations to support effective climate action.

Since the 2021 CAP, significant progress has been made at the international, federal, state, and local levels to create policies and implement programs to fund climate action, advance regulations for GHG reductions, and implement projects to improve Pennsylvania's climate resilience and adaptation. New federal legislation, notably the Inflation Reduction Act (IRA) and the Infrastructure Investment and Jobs Act (IIJA)—also known as the Bipartisan Infrastructure Law (BIL)—has created nearly $300 billion of federal funding for clean energy and climate action. This report charts a path forward to secure such funding opportunities and produce valuable benefits for all Pennsylvanians, including cleaner air, more green jobs, a healthier environment, sustainable energy security, and improved community resilience to climate impacts. A multi-agency effort has been underway across the Commonwealth to take decisive climate action in multiple sectors with the support and collaboration of private sector partners, community-based organizations, climate science experts, and diverse coalitions of engaged Pennsylvanians. These efforts range from educational campaigns to conservation efforts to financing effective energy efficiency measures.

Climate Change Impacts in the Commonwealth

Climate change is already creating significant impacts to Pennsylvania's people, environment, infrastructure, and economy, and these impacts are projected to worsen as climate change accelerates. The recommendations presented in this plan are based on the most recent climate science and a multi-sector analysis of Pennsylvania's climate risks and potential impacts, as captured in detail in the 2024 CIA. Key findings from the CIA include:

- Significant increases in average temperatures, serious precipitation events, and inland flooding are the greatest climate risk hazards through mid-century.
- Heat waves will become increasingly common and will create health and economic risks for vulnerable populations, including low-income populations, the elderly, pregnant women, people with certain mental health conditions, outdoor workers, and those with cardiovascular conditions. These risks are and will continue to be acute in areas subject to the urban heat island effect.
- Landslides and sea level rise pose relatively low risks across the Commonwealth but can cause severe impacts in the locations where they occur, especially, for sea level rise, those near the Delaware estuary.

It is up to government and private leaders, community organizations, and all Pennsylvania citizens to take action to prevent the worst of these climate impacts to secure a resilient and prosperous future in the Commonwealth.

Greenhouse Gas Inventory and Forecasts

Pennsylvania's latest GHG inventory—from 2020—provides a holistic accounting of GHG emissions in the Commonwealth, disaggregated by economic sectors. The inventory is used to track current emissions and GHG reductions over time, and it forms the basis of future emissions modeling scenarios and proposed GHG reduction strategies. Notably, the COVID-19 pandemic affected GHG emissions in 2020, particularly for sectors like transportation, as public health policies affected travel and telecommuting increased for some Pennsylvanians. The GHG emissions modeling methodology accounts for this outlier year to ensure projections reflect emissions trends that transcend the outlier data in 2020.

Emissions in 2020 were 25.9% lower than 2005 baseline emissions. The most significant and consistent trends driving reductions include a power sector fuel shift from coal to natural gas and improvements in energy efficiency across many sectors. These trends are projected to continue as a result of new and existing policies and climate investments at the local, state, and federal levels.

GHG emissions have declined across most sectors including:

- Emissions from electricity generation (decreased 10.4% from 2019 to 2020 and 44.4% from 2005 to 2020).
- Emissions from transportation have decreased 26.2% since 2005 (partially from impacts of COVID on transportation sector).
- Emissions from the residential and commercial sectors have decreased 25.2% and 17.1% respectively, since 2005.

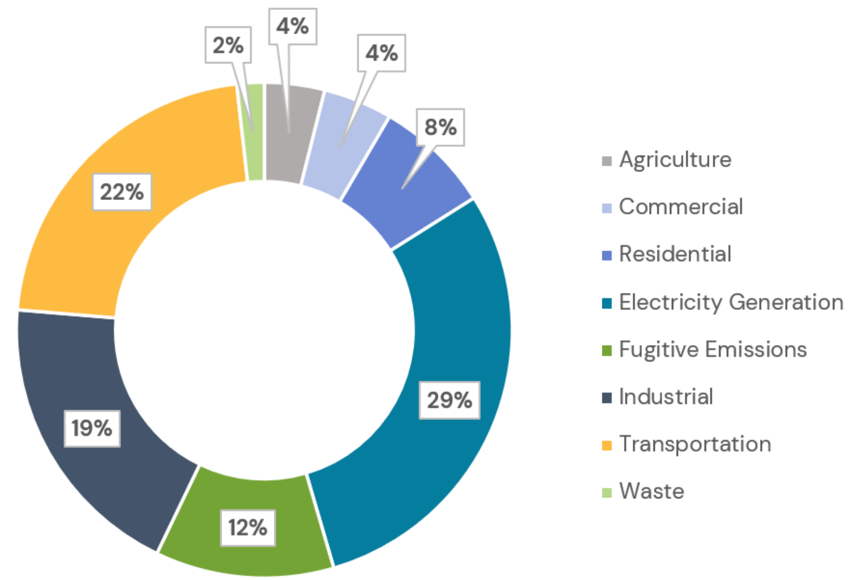
Fugitive emissions from energy production (natural gas and oil systems) have increased, as have industrial emissions (both fuel consumption and process emissions), and agriculture emissions (resulting from agricultural soil management, liming, and urea fertilization). The three largest sources of emissions in Pennsylvania in 2020 were:

- Electricity Generation (29% of gross emissions),
- Transportation Fuel Consumption (22% of gross emissions), and
- Industrial Emissions (19% of gross emissions).

GHG Reduction Strategies

The GHG reduction strategies proposed in the 2024 CAP will put Pennsylvania on track to approach its 2030 and 2050 GHG reduction goals. DEP has prioritized 22 strategies to reduce GHG emissions, five of which are new to this update (Table 1). Strategies from previous CAPs have been updated to include strategy progress highlights, innovations in technology, new climate regulations and funding opportunities, community-driven equity considerations, and the latest program data to improve strategy implementation. The strategies are categorized into eight key sectors:

Figure 1. Pennsylvania 2020 GHG Emissions by Sector



- Built Environment (B),
- Transportation (T),
- Industrial (I),
- Fuel and Gas Systems (F),
- Power Generation (P),
- Waste (W),
- Land Use and Agriculture (L), and
- Cross Cutting Technology (C).

This plan does not reflect every action happening across the Commonwealth; however, these strategies were carefully prioritized on the basis of GHG reduction potential, costs, job impacts, and the value of co-benefits each will provide. Together, these strategies create a pathway toward significant GHG reductions, improved climate resilience, and co-benefits like better health outcomes, sustainable economic growth, and a more equitable society.

Table 1. Summary of Emissions Reductions Strategies by Sector

Sector	Strategy Name	GHG Emissions Reduction1 (2050)
Built Environment	**B1. Building Codes**: Improve energy efficiency of new buildings and major retrofits through codes.	**0.43 MMTCO$_2$e**
Built Environment	**B2. Electricity Efficiency in Buildings**: Deploy electricity efficiency in existing buildings.	**Included in P1.**
Built Environment	**B3. Gas Efficiency in Buildings**: Deploy gas efficiency in existing buildings.	**1.07 MMTCO$_2$e**
Built Environment	**B4. Building Electrification**: Deploy gas and fuel oil alternatives in existing buildings.	**7.43 MMTCO$_2$e**
Built Environment	**B5. Onsite Solar**: Deploy onsite solar, distributed energy resources, and battery systems in buildings.	**Included in P1.**
Transportation Systems	**T1. TRANSIT AND MULTIMODAL IMPROVEMENTS**: **Expand transit, transit-oriented design, and multimodal transportation**. ***New***	**1.88 MMTCO$_2$e**
Transportation Systems	**T2. Light-Duty Vehicle Electrification**: Deploy EV and associated infrastructure.	**13.86 MMTCO$_2$e**
Transportation Systems	**T3. Zero Carbon Medium- and Heavy-duty Vehicles**: Implement low-carbon fuels and deploy zero carbon medium- and heavy-duty vehicles and associated infrastructure.	**11.49 MMTCO$_2$e**
Industrial	**I1. Industrial Efficiency**: Deploy electricity and gas efficiency in the industrial operations.	**7.10 MMTCO$_2$e**

[1] Annual reductions in GHG emissions compared to BAU Reference.

Sector	Strategy Name	GHG Emissions Reduction (2050)
Industrial	**I2. Gas, Fuel, and Process Decarbonization**: Electrify industrial uses, change processes, and deploy gas and fuel oil alternatives in industrial operations.	**8.39 MMTCO_2e**
Fuel & Gas Systems	**F1. Operational Efficiency**: Reduce methane emissions across oil and gas operations.	**7.25 MMTCO_2e**
Fuel & Gas Systems	**F2. Biomethane:** Expand use and generation of biomethane fuels.	**9.49 MMTCO_2e**
Fuel & Gas Systems	**F3. INACTIVE AND MARGINAL WELLS: Reduce methane emissions from inactive and marginal conventional oil and gas wells. *New***	**4.48 MMTCO_2e**
Power	**P1. Net Zero Grid**: Build a net zero carbon electricity grid.	**39.42 MMTCO_2e**
Power	**P2. DISTRIBUTION AND TRANSMISSION GRIDS: Ensure that electricity grid is ready for electrification related to peak load impacts and reliability. *New***	**Included in P1.**
Waste	**W1. Sustainable Organic Waste Management:** Divert organic waste from landfills and incinerators.	***Not Quantified***
Waste	**W2. Sustainable Construction Waste Management:** Support construction material salvage and reuse along with adaptive reuse of buildings.	***Not Quantified***
Land Use & Agriculture	**L1. Agriculture Best Practices:** Implement agriculture best practices for emissions reduction.	**0.02 MMTCO2e**
Land Use & Agriculture	**L2. Agriculture Best Practices:** Implement agriculture best practices for carbon sequestration.	**2.78 MMTCO_2e**
Land Use & Agriculture	**L3. Land and Forest Management:** Increase natural sequestration in Pennsylvania's land and forests.	**1.16 MMTCO2e**
Cross Cutting Technology	**C1. HYDROGEN FUELS: Expand use and generation of hydrogen fuels. *New***	**9.41 MMTCO_2e**
Cross Cutting Technology	**C2. CARBON CAPTURE, UTILIZATION, AND STORAGE: Deploy and continue to pursue new carbon capture technologies for power and industrial systems. *New***	**2.80 MMTCO_2e**

Key Takeaways from Strategies Modeling

If Pennsylvania pursues the strategies outlined in this CAP, the state will make significant progress toward their established climate goals; however, more action will be needed in difficult to decarbonize sectors like industrial processes to achieve these targets (see Table 2 and **Error! Reference source not found.**).

- By implementing all modeled strategies, **Pennsylvania could reduce GHG emissions in 2030 by more than 40% below 2005 levels**.
- **Pennsylvania will near the path to net zero by 2050,** reducing GHG emissions by nearly 80% from 2005 levels with the implementation of all modeled strategies in all sectors.
- **More reductions will be needed to meet both short (2030) and long (2050) term climate targets.**
- **A clean grid is central to decarbonization** of nearly every sector including buildings, transportation, and industry.

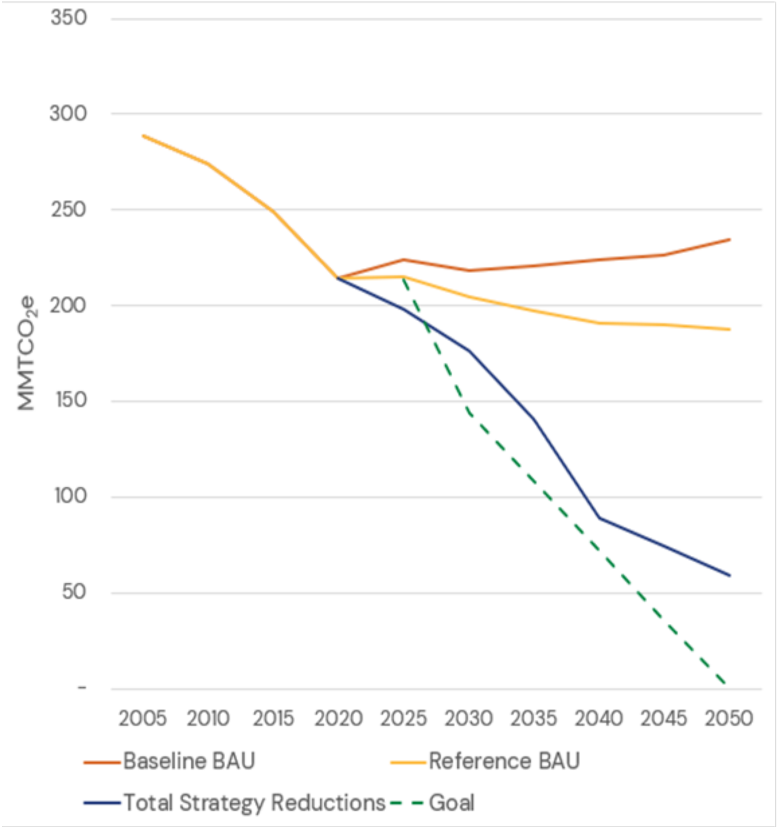
In addition to the climate change related benefits discussed in the study, economic modeling conducted for the CAP strategies indicates implementation of strategies can also create local jobs in the Commonwealth and sustain economic growth in decades to come. Our modeling suggests that taken together, **these strategies can lead to over 700,000 cumulative job-years through 2050 with an average annual job growth of over 26,000,** which translates to an increase of about 0.3% over the business-as-usual baseline.

While some strategies analyzed under this CAP can lead to small job losses, in aggregate, the strategies lead to net positive job impacts for the Commonwealth. These job gains also lead to an average annual increase of close to $260 million in-state economic output, an increase of 0.02% over the business-as-usual baseline.

Table 2. Modeled GHG Reduction Results Compared to Set Goals

Year	Goal	Results
2030	50% reduction	40%
2050	Net zero emissions	80%

Figure 1. Comparison of Strategy Results to Baseline Scenarios and Goal



Climate Change Adaptation Strategies

Many Pennsylvanians are already experiencing the impacts of climate change, and climate-related risks to infrastructure, public health, energy, and food security are projected to worsen in the years and decades to come. To reduce these risks, DEP developed ten adaptation strategies that will help Pennsylvania's people, infrastructure, economy, and environment better react to and recover from climate impacts (Table 3). The strategies build on the adaptation pathways described in the 2021 CAP and the adaptation priorities of the 2024 CIA. These strategies represent existing adaptation efforts taking place across the Commonwealth while incorporating best practices from other states and actors and identify specific actions to advance adaptation and enable supporting actions by other actors through improved coordination.

Table 3. Adaptation Strategies

Strategy
A1. State Agency Coordination: Coordinate across agencies and jurisdictions on climate adaptation and resilience efforts. Designate a chief resilience officer or other champion that reports to the state, local, or municipal executive to lead these efforts.
A2. Local Adaptation Program: Incentivize or otherwise promote local municipal and regional climate change vulnerability assessments and adaptation plans and establish grant programs or financing mechanisms to fund associated adaptation projects that build local resilience.
A3. Nature-based Solutions: Promote the use of green infrastructure and nature-based solutions (including urban trees) to mitigate storm water impacts and urban heat island effects and incentivize its use in new developments through existing state economic development programs and brownfield redevelopment programs.
A4. Utility Climate Risk Analysis: Encourage regulatory bodies to require climate risk analysis for water supply and energy utilities, identifying specific risks, timeframes and locations of impact, resilience actions to mitigate identified risks, as well as any gaps needing additional research.
A5. Enhanced Workplace Health and Safety Protections: Promote state and local adoption of legal protections, requirements, and best practices for workplace health and safety (such as expanded PPE use, multi-lingual heat safety guides, and additional protections for vulnerable groups) to protect workers from exposure to dangerous heat conditions and poor air quality.
A6. Evaluation of Equity Impacts: Require the evaluation of EJ areas and other historically disadvantaged and marginalized groups when evaluating climate risk and adaptation strategies in order to ensure equitable distribution of risks and benefits.
A7. Climate Resilient Design Guidelines: Adopt guidance to incorporate climate projections into built infrastructure design (such as requiring flood protection measures through building codes based on the Federal Flood Risk Management Standard).
A8. Enhanced Emergency Management: Expand existing extreme weather emergency response management to consider the increased frequency and severity of extreme weather events due to climate change, through measures that include but are not limited to enhanced early warning systems, additional staffing and equipment, public outreach, and additional training.
A9. Property Risk Disclosure: Require property owners to disclose information about a building's propensity to flood when renting or selling the property and include information on whether mold remediation has been or will need to be conducted.
A10. Health Impacts Tracking: Encourage public health agencies to track and analyze health data to better understand climate-related health impacts (including heat, flooding, vector-borne diseases, and air quality impacts from wildfires or an increase in ground-level ozone) and take steps to address these impacts, giving particular consideration to disparate impacts.

Implementing the Plan

This CAP builds on numerous ongoing efforts by pairing strategic climate planning with tangible implementation considerations to achieve the greatest total benefits from new and existing climate actions. This plan provides some flexibility in approaches to achieve Pennsylvania's climate goals, meaning that there are several pathways that the Commonwealth could take to achieve its goals. As such, this plan does not detail specific implementation steps but rather emphasizes key considerations for implementation, like roles and responsibilities across actors, economic and social considerations, monitoring and evaluation guidance, and other best practices for implementation.

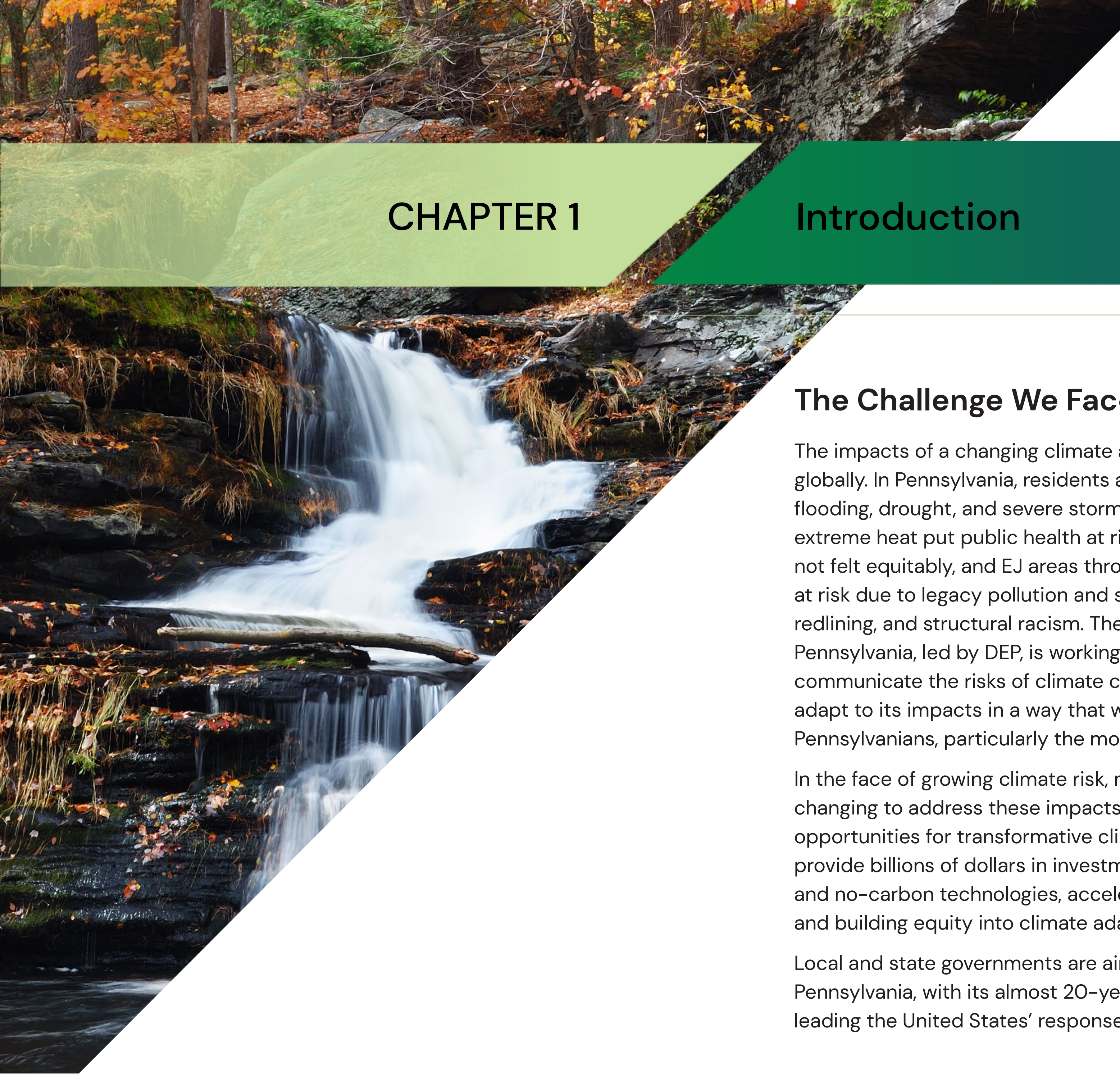
DEP recognizes that the success of this plan relies in part on changes to Pennsylvania's policy landscape; toward that end, DEP developed recommendations for legislation to support key climate strategies. These legislative recommendations reflect changes in Pennsylvania's energy landscape, technology and policy innovations, and the needs expressed by Pennsylvanians.

Climate change will not affect all Pennsylvanians equally. Some are more vulnerable to impacts due to their location, income, health, housing, or other factors. The 2024 CAP carefully examines all proposed strategies through an equity lens to increase access, advocacy, and accountability, and to ensure that strategies proactively address issues of environmental and climate justice. Centering community voices and listening to each community's unique needs and local context will be crucial to ensure the CAP is implemented equitably and beneficially for all Pennsylvanians.

Legislation Recommendations from the DEP

To support climate priorities and needs the 2024 Climate Action Plan includes seven DEP-developed legislation recommendations, which are outlined in Chapter 7.

- Building Code Reform
- Enabling Community Solar
- Zero Emissions Vehicle Targets
- Low Carbon Fuels Standard
- Pennsylvania Reliable Energy Sustainability Standard (PRESS)
- Pennsylvania Climate Emissions Reduction Act (PACER)
- Hydrogen and CCUS Legislative Package



CHAPTER 1 Introduction

The Challenge We Face

The impacts of a changing climate are being felt both locally and globally. In Pennsylvania, residents are increasingly threatened by flooding, drought, and severe storms, while rising temperatures and extreme heat put public health at risk. These climate impacts are not felt equitably, and EJ areas throughout Pennsylvania are more at risk due to legacy pollution and systemic barriers such as redlining, and structural racism. The Commonwealth of Pennsylvania, led by DEP, is working to better understand and communicate the risks of climate change, mitigate its causes, and adapt to its impacts in a way that will ensure the wellbeing of all Pennsylvanians, particularly the most vulnerable ones.

In the face of growing climate risk, national and local policies are changing to address these impacts and provide increased opportunities for transformative climate action. The IIJA and the IRA provide billions of dollars in investment aimed at expanding low- and no-carbon technologies, accelerating a just energy transition, and building equity into climate adaptation efforts.

Local and state governments are aiming to take similar actions, and Pennsylvania, with its almost 20-year history of climate action, is leading the United States' response to climate change.

2024 CAP Vision

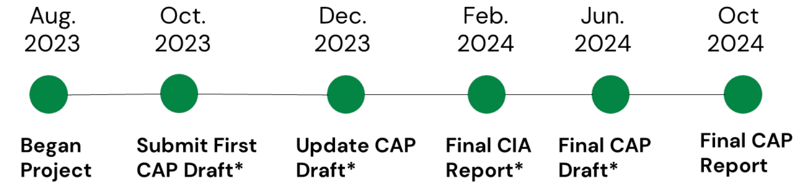
At this critical time, the 2024 iteration of Pennsylvania's CAP builds upon the work of previous climate action plans and aims to align Pennsylvania's priorities with unprecedented federal investments. The 2024 CAP is focused on moving beyond the Act 70 mandate to create an even bolder vision that meets the Commonwealth's climate goals and provides greater emphasis on addressing climate impacts to Pennsylvania's EJ areas. Updated with the latest climate science, informed by other successful climate work across the US, and with a stronger focus on implementation than in previous CAPs, the 2024 CAP is a blueprint for climate action and includes potential legislative changes that can best facilitate effective GHG reduction activities throughout Pennsylvania.

Purpose of this Plan

This CAP considers the dynamic and complex implications of climate change for Pennsylvania's communities—from the impact of heat events on urban residents to the economic impacts of reduced agricultural yields on famers—and proactively provides a path that addresses climate challenges and ensures a more equitable future.

This 2024 CAP provides DEP's plan to limit Pennsylvania's contribution to climate change and to adapt to the present and future effects of climate change. It identifies key actions that are needed by all Pennsylvanians. The strategies in this plan will harness transformative opportunities at the federal level, reflect the needs of local communities, and enhance collaboration between interested parties and the Pennsylvania government. The 2024 CAP will incorporate the input of all communities, especially low-wealth and minoritized groups, into the climate action planning. This input came through the feedback from the Climate Action for EJ Communities (CAEJC) Program and this outreach will continue throughout the plan's implementation process.

CAP Development Process/CCAC Engagement



*Incorporated CCAC Feedback

The development of this CAP builds on historical and current climate work of DEP and other actors. DEP led the development of the Impact Assessment (CIA) and this CAP and sought feedback from the CCAC, as mandated in Act 70. The CCAC membership brings Pennsylvania expertise to the planning process, and members advocate for the interests of a diverse and comprehensive group of organizations and interests across the Commonwealth. These members represent the scientific, business and industry, transportation, environmental, social services, outdoor and sporting, labor, and other communities, in addition to the ex-officio membership of the Secretary of the Department of Conservation and Natural Resources (DCNR), the Secretary of Community and Economic Development and the Chair of the Pennsylvania Public Utility Commission (PA PUC) or their designees. Engagement with other interested parties like sibling agencies, (e.g., DCNR, Pennsylvania Department of Health, the Pennsylvania Department of Agriculture, Pennsylvania Department of Transportation [PennDOT]), and other interested parties (e.g., PA PUC and the GreenGov Council) were critical to the 2024 CAP update.

Prioritizing Equity & Environmental Justice

Equity and EJ are key priorities of DEP and of this plan. Aligning with the recently updated Pennsylvania Interim Final Environmental Justice Policy (EJ Policy), the 2024 CAP is heavily informed by the findings of the CAEJC Program which conducted extensive outreach efforts aimed at identifying and supporting actions to help Pennsylvanian communities facing EJ issues adapt to climate change while striving to lower GHG emissions.

Key Values

This 2024 CAP aims to serve environmental justice areas (EJ areas), which encompass a diverse range of Pennsylvania communities from rural areas, including coal towns, to dense urban centers. While these communities face different stressors, their climate-related impacts and opportunities considered in this plan often overlap. As such, the full range of these communities will be referred to collectively in this CAP. Additionally, this plan addresses EJ as a collection of equity-related considerations and this encompasses climate justice. Climate justice focuses on the unequal impact of climate change on marginalized or vulnerable populations. Climate justice seeks to ensure equitable protection from climate impacts, recognizing that climate change impacts include a risk of worsening equity outcomes.

In each strategy proposed, the CAP considers ways to expand equity by increasing **accessibility** to climate actions, incorporating **advocacy** for underserved constituencies, and maintaining **accountability** throughout CAP implementation.

Accessibility: Program design and implementation phases will consider key accessibility areas such as affordability, language, workforce development, technology, physical, and cultural relevance. Mechanisms for accessibility include:

- **Affordability:** Upfront and overall costs.
- **Cultural relevance:** Individual identity (i.e. race, generation) and community context (i.e. locality, history, geography).
- **Language:** Dialect, translation, and plain language (understandability).
- **Technology:** Broadband availability and reliability, device functionality and usability (user interaction).
- **Physical:** Transportation, ADA, and infrastructure condition.
- **Workforce:** Training for new and existing workforce, expanded opportunities, and diversification.

Advocacy: DEP will uplift and incorporate the voices of community advocates, understanding that actions taken by DEP and partner organizations prioritize the wellbeing of all Pennsylvania constituents. DEP understands that types and degrees of advocacy should vary based on the communities considered. Mechanisms for advocacy include:

- **Community engagement:** Inclusion of informal, ad-hoc groups comprised of community members.
- **Community-based organization (CBO) partnership:** Continuous partnership with formal, existing groups.
- **Interagency collaboration:** Align efforts across governmental agencies.
- **Key community leaders:** Identify and regularly elevate trusted leaders representing prioritized communities.

Accountability: DEP and organizations responsible for implementing CAP strategies will fulfill expectations set forth by the CAP, practicing transparency when expectations are unable to be met due to internal or external circumstances. Transparency in such efforts will also garner public buy-in to critical actions in the CAP that will only be successful with widespread support. Mechanisms for accountability include:

- **Inclusive processes:** Regular community input and co-design.
- **Budget transparency:** Disclose funding sources and distribution.
- **Decision-making transparency:** Share adopted and rejected decisions.
- **Burden acknowledgment:** Understand and mitigate where strategies create additional or unintended burdens.

How We will Speak to Equity and Environmental Justice

Throughout the history of the Commonwealth, policies of divestment and discrimination have produced persisting inequities which can be seen in communities across Pennsylvania. Low-wealth, minoritized communities are disproportionately impacted by climate change because of a variety of risk factors, including but not limited to:

- Disproportionate exposure to climate hazards in the home or at work, especially for manual laborers and the unhoused;
- Limited access to cost-prohibitive adaptation options like air conditioning and storm proofing; and
- Higher risk of medical conditions, like respiratory and cardiovascular illness, which worsen under increased heat stress and air pollution.

To effectively address and mitigate climate change, adaptation and GHG reduction measures must meaningfully address the needs of these populations who are most at risk.

Broadly speaking, climate mitigation and climate adaptation both serve to improve equity and advance environmental justice, though in different ways. GHG reduction strategies primarily minimize pollution, which provides immediate and long-term human and environmental health benefits and brings additional co-benefits to EJ areas such as job opportunities, increased transportation options and access, and potentially lower energy bills. Additionally, GHG reductions efforts aim to keep the Commonwealth on a lower emissions trajectory, and limit contributions to climate risks experienced by EJ areas. Climate adaptation activities can provide key benefits to EJ areas by anticipating impacts to vulnerable communities and aiming to reduce risks before disaster strikes, saving both lives and property. Additionally, adaptation activities are often significantly less expensive than repairs that would be needed after climate disasters, meaning they are cost effective for the benefits that they provide, which gives communities the opportunity to reprioritize resources and funding that would have otherwise been used for cleanup to meet local needs.

Considerations and implications for accessibility, advocacy, and accountability within each emissions sector are discussed. Lastly, Chapter 8 of this report discusses the practical aspects of translating climate action planning into reality and discusses principles for ensuring equitable implementation.

Throughout the report, discussions of equity and EJ are identified by orange headers and callout boxes.

CAP Contents

- **Chapter 2: Pennsylvania Climate Landscape** describes key climate change risks and drivers, the implications of these risks for Pennsylvanians, and the status of climate action in the Commonwealth.
- **Chapter 3: Greenhouse Gas Emissions** summarizes the most recent GHG inventory and the methodology for calculating the baseline inventory, the results of the assessment, and limitations.
- **Chapter 4: Greenhouse Gas Reduction Opportunities** summarizes the approach for identifying opportunities and details these opportunities for Pennsylvania to reduce GHG emissions in key sectors.
- **Chapter 5: Climate Change Impacts** provides a summary of the key climate impacts facing Pennsylvania, as identified by the 2024 Climate Impact Assessment.
- **Chapter 6: Adaptation Opportunities** identifies and prioritizes adaptation strategies and pathways and assesses costs and benefits.
- **Chapter 7: Legislative Recommendations** outlines DEP's recommended legislation options to support implementation of the proposed CAP strategies.
- **Chapter 8: Implementing Climate Action** focuses on the practical aspects of translating climate action planning into reality and highlights approaches for equitable and beneficial implementation.
- **Appendix A: Key Terms** defines terms and acronyms.
- **Appendix B: Methodology Details** provides additional detail on how GHG reductions were modeled.
- **Appendix C: Federal Funding Opportunities** provides a description of key federal funding sources that could be used to support the implementation of this CAP.
- **Appendix D: Embodied Carbon** defines embodied carbon and elaborates on how to address it through assessment techniques, mitigation strategies, and regulations.

Key Updates from 2021 Report

The climate landscape has dramatically changed since 2021, and the 2024 CAP reflects these policy, leadership, and technology changes.

International Climate Progress

UN goals

The UN continues to base its climate goals on the Paris Agreement of 2016, which targets global average temperature increases well below 2°C, with an aim to keep temperature increases below 1.5°C. The United States rejoined the Paris Agreement in 2021. In 2023 the first global stocktake of emissions took place during COP28, highlighting where countries and stakeholders have collectively made progress toward meeting the goals of the Paris Agreement, and where there are additional efforts needed. As indicated in the global stocktake, there is a glaring gap in emissions reductions, requiring 43% reductions by 2030 and 60% reductions by 2035 from 2019 levels to meet the 1.5°C goal.

IPCC updates

IPCC released its 6th assessment synthesis report in March 2023, the end of an 8-year cycle updating climate change knowledge from the 5th assessment report. Key findings from the 6th assessment include:

- Human activities mainly through the emission of GHGs have already caused 1.1°C in warming.
- Climate impacts on people and ecosystems show more severe and widespread current and projected impacts.
- There has been consistent growth in adaptation and resilience measures. However, to address the gap between projected reductions from plans and the expected reductions based on current emissions significant increases in climate financing is needed this decade.
- Existing climate impacts that cannot be fully mitigated have already occurred, leading to losses and damage.
- To align with 1.5°C pathways, emissions will need to peak by 2025, we will need to rapidly shift away from fossil fuels, and we will have to bolster carbon removals.
- If significant efforts are not made to ensure a just transition both climate change, and the efforts to adapt and mitigate climate change can lead to increased inequity.

The 6th assessment report also lays out ten key solutions that can be pursued to mitigate climate change (Figure 2).

COP 28 outcomes

The 28th Conference of the Parties (COP), held at the end of 2023 in Dubai laid out several key ambitions in addressing climate change. 197 nations and the EU participated in policy discussions with representatives from civil society, business, Indigenous Peoples, youth, philanthropy, and international organizations. An agreement signaling the "beginning of the end" of the fossil fuel era through a swift, just, and equitable transition was agreed upon, supported by deep emission reductions and scaled-up financial commitments. Other agreements included new funding for loss and damage, enhanced efforts to strengthen resilience, linking climate and conservation, ramping up practical climate solutions and

Figure 2. Ten key solutions outlined in the IPCC 6th assessment report, *Source: IPCC AR6*

developing an enhanced transparency framework to support the implementation of the Paris Climate Accords, as established at COP 21. While all agreements made under previously held COPs are legally binding under international law, there is no clear international enforcement mechanisms to support this commitment, so federal and state laws are needed to uphold any US-specific commitments under COP.

Federal Policy

Since 2021, numerous federal policies have been passed to support decarbonization and climate adaptation and resilience-building efforts through increased funding, tax credits, and other supportive policies. Noteworthy legislation includes the American Innovation and Manufacturing (AIM) Act, the IIJA, the IRA, and the CHIPS and Science Act. These policies aim to reduce emissions and stimulate clean American industry. A common theme across these policies is alignment with the White House's Justice40 initiative, which[2] aims to ensure that historically disadvantaged communities also benefit from these efforts. Additionally, a range of federal regulatory changes have been initiated that could affect emissions from the electricity grid, gas systems and other economic sectors. APPENDIX C contains a list and description of key federal funding opportunities that align with these policies and can support climate action. Where relevant, funding and other federal opportunities that align and could directly support strategies in the CAP are also highlighted in the body of this report.

5th National Climate Assessment

The 5th National Climate Assessment (NCA5) was released in November of 2023. This represents the most updated, authoritative information on climate change released by the federal government, NCA5 analyzes the impacts of climate change impacts, risks, and responses and provides the scientific foundation to support informed decision-making across the United States. NCA5 covers 32 chapters from an overview of climate change, the physical science support climate change trends and processes, national topics including sectors, environments, and human systems, regional chapters for specific areas in the United States, and chapters of adaptation and mitigation responses.

Technological Advancement

Advances in key emissions reduction technologies have continued to evolve, and they are increasingly more developed. This CAP update highlights these cutting-edge areas, particularly carbon capture, utilization, and storage (CCUS) and hydrogen. Additionally, existing technologies such as electric vehicles (EV), solar photovoltaic (PV), and batteries have become more cost competitive and prevalent in US markets.

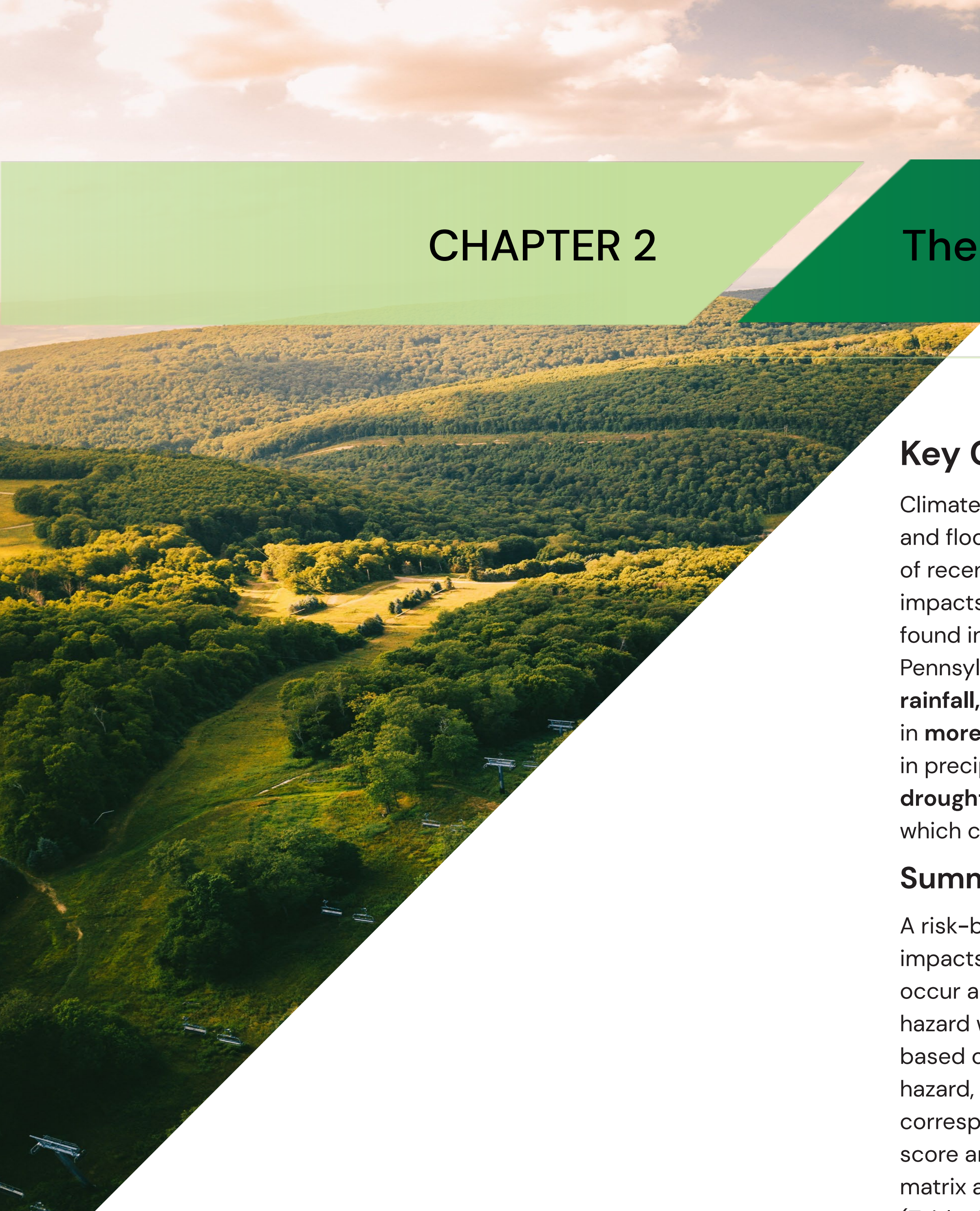
New CAP Items

The 2024 CAP includes multiple new components, building from the 2021 CAP and provides the latest emissions and energy analysis for strategies and modeling for the Commonwealth, and has a greater emphasis on addressing the needs of EJ areas, where the impacts of climate change are disproportionately felt. The report includes an energy rate analysis that evaluates how emissions reduction strategies impact electricity and gas costs, and a view of embodied carbon impacts. Additionally, example costs and benefits are provided at the household level to clearly indicate the socioeconomic impacts experienced by an average Pennsylvanian. This update also includes key climate adaptation opportunities which can be used to reduce the impact from climate change in Pennsylvania. A final update in this iteration of the report is that additional detail has been provided around DEP legislative recommendations to aid in implementing the proposed strategies.

[2] Justice40 is a federal program created by Executive Order 14008 that made it a goal to have 40% of federal investments flow to disadvantaged communities. Many federal programs in the IRA and IIJA are required to meet this goal.

CHAPTER 2

The Pennsylvania Climate Landscape



Key Climate Change Risks and Drivers

Climate change is already affecting Pennsylvania. Intense storms and floods, air quality emergencies, and heat waves are examples of recent events that post serious economic, health, and equity impacts across the Commonwealth. The latest climate projections found in the 2024 Climate Impact Assessment reinforce that Pennsylvania is expected to see **increases in temperatures, rainfall,** and **weather variability** over the coming decades resulting in **more frequent and dangerous heat events**. Increased variability in precipitation patterns is also expected to cause **periods of drought** as well as **more frequent or serious heavy rain events**, which can result in flooding.

Summary of Current and Future Climate Risks

A risk-based approach was used to assess and prioritize climate impacts and to evaluate the likelihood that a climate hazard will occur and the magnitude of its consequences. For the state, each hazard was analyzed, and an overall risk score was calculated based on likelihood of the hazard occurring, consequence of the hazard, and confidence rating. To compute a total risk score and corresponding risk rating for each climate hazard, the likelihood score and overall consequence score are multiplied together. A risk matrix and scoring rubric are then used to determine total risk (Table 4).

Table 4. Risk rating matrix and rating rubric

Likelihood	Consequence: Minor	Consequence: Limited	Consequence: Critical	Consequence: Catastrophic
Highly Likely	4	8	12	16
Likely	3	6	9	12
Possible	2	4	6	8
Unlikely	1	2	3	4

Risk Score (low end inclusive)	Rating
12+	Extreme
6 – 11.9	High
3 – 5.9	Medium
1 – 2.9	Low

Pennsylvania is currently at a high risk of heavy precipitation and flooding[3] but is at a medium or low level of risk from other key climate hazards. However, by 2050, climate risks are expected to increase, particularly from rising average temperatures and more frequent heat waves. Key climate hazards of extreme heat, extreme precipitation, sea level rise, and tropical and extra-tropical storms, day through 2050 by varying degrees. The Commonwealth subsequently needs to plan actions to manage more significant and complex climate risks in the future.

Climate change could have significant impacts to Pennsylvania's people, environment, infrastructure, and economy. Key findings from the 2024 CIA include:

- **Significant increases in average temperatures** and **serious precipitation events and inland flooding** are the two highest climate risk hazards that will occur by mid-century. Both hazards could affect the entire state and all sectors. Pennsylvanians in EJ areas are at a higher risk of displacement from flooding events.
  - The average annual daily temperature of 48.3°F (9.1°C) is expected to increase by 6.7°F (3.7°C) by 2050 and up to 10.4°F (5.8°C) by 2100.
  - Pennsylvania will see higher annual precipitation, more extreme precipitation, and more days of drought through 2100. Extreme precipitation events will become more common and more intense while the number of consecutive days without rain will also increase.

[3] Heavy precipitation and inland flooding were analyzed together as a single hazard, based on the likelihood of an event and the severity of the related consequences to human health, economy, infrastructure and environmental justice using available floodplain and projected precipitation data.

- **Heat waves will become increasingly common.** The length of the longest heat wave seen in a year will increase from the historical level of 2.3 days to 8.8 days by 2050 and 19.3 days by 2100. Heat waves are approximated by the annual number of days above 90°F (32.2°C) and 95°F (5°C) as well as the number of consecutive days above 90°F and 95°F. Heat waves will create health and economic risks for vulnerable populations, including low-income populations, the elderly, pregnant women, people with certain mental health conditions, outdoor workers, and those with cardiovascular conditions. These risks are and will continue to be acute in areas subject to the urban heat island effect.
- **All key climate hazards—but particularly 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 and, indirectly,

Key Potential Consequences from Heavy Precipitation and Flooding

- Flood damage to homes, businesses, and critical energy and transportation infrastructure, particularly those located in floodplains.
- Health risks from injury from flood waters or water quality contamination.
- Agricultural impacts including increased risk of runoff, erosion, and nutrient leaching, and greater challenges to timing of crop planning.
- Wide-ranging economic impacts, from disruptions to recreation and tourism to infrastructure service disruptions.
- Disproportionate impacts in vulnerable communities.

Key Potential Consequences from Increasing Average Temperatures

- Increase in health and safety risks, such as more days with hazardous heat conditions for outdoor workers and reduced air quality from higher ground-level ozone and increased pollen.
- Increased energy burden for low-income households.
- Gradual shifts in growing seasons, suitable habitat range, and ecosystems.
- Increase in pests, invasive species, and diseases (e.g., Lyme disease).
- Change in outdoor recreational opportunities (e.g., severe reduction in snow- and ice- based winter recreation and tourism).

Key Terms

Risk—The chance a climate hazard will 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).

Climate hazard—Changes or events related to global climate change. Climate hazards can be discrete (e.g., severe storms) or ongoing (e.g., increasing average temperatures).

Impact—The effect of a climate hazard.

Likelihood—The probability or expected frequency a climate hazard is expected to occur.

Consequence—A measure of the severity of impacts from a climate hazard.

vector-borne illness. Flooding increases the risks of direct injury from flood waters and of illness caused by contaminated water.

- **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 its ecology and threaten the built infrastructure near the tidal zone. Landslides can have severe consequences if they cut off critical transportation routes, particularly in rural areas of Southwest Pennsylvania.

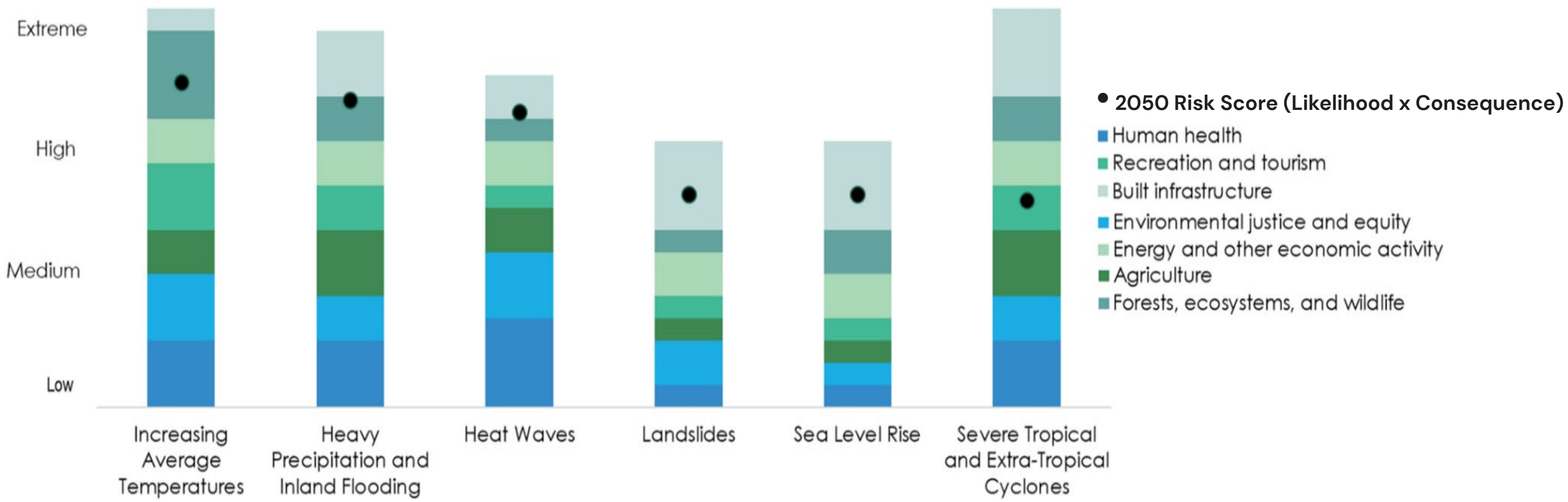
Climate Risks to Pennsylvanians

Climate hazards have varying likelihoods of occurring and when they do occur, the severity of consequence may differ depending on the type of risk. Figure 3 identifies key climate hazards facing Pennsylvania and the sectors at risk, the level of risk associated with each of these hazards, and the relative level of total vulnerability that each of these key sectors has to climate change.

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 should also take care that these inequitable impacts are addressed, and that adaptation efforts do not inadvertently exacerbate inequities.

Health is one of the main ways that climate change will impact citizens' daily lives. Populations at greater risk from heat-related hazards include the elderly, low-income communities, pregnant

Figure 3. Total consequences and risks by hazard



women, individuals with cardiovascular disease, and outdoor workers. Flooding and severe cyclones can also have severe health impacts as critical services are disrupted and conditions are more hazardous. Figure 4 summarizes how climate change impacts human health.

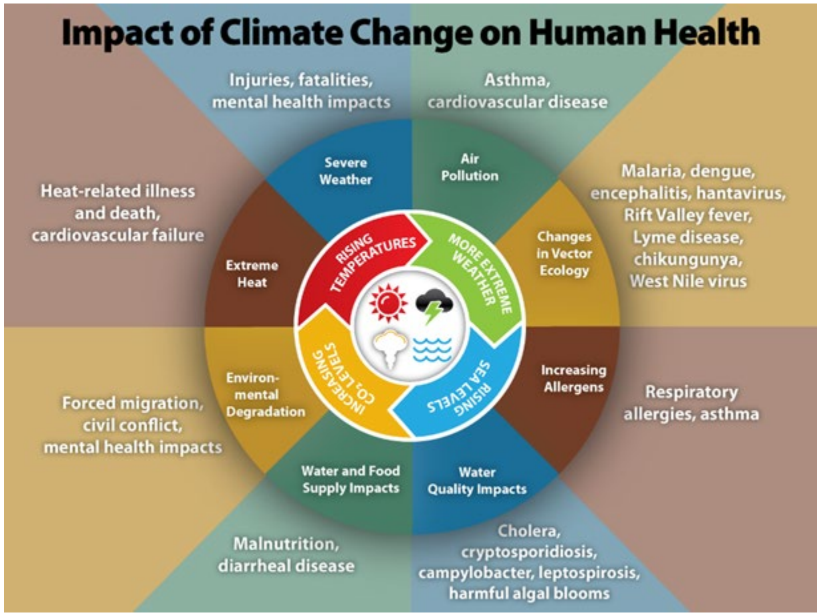
For changes that will come on gradually, such as rising temperature, Pennsylvania has an opportunity not only to reduce potential harm but also to capitalize on potential positive changes. This is particularly true for rising average temperature, which could enable the cultivation of warmer-weather crops, expand warm-weather recreation and tourism, and lower wintertime heating energy demand.

Agriculture is poised to harness the power of many unique growth opportunities resulting from climate adaptation. Longer growing seasons and higher temperatures may provide opportunities to grow new, warmer-weather crops (e.g., soybeans, peaches).

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

Figure 4. Impacts of climate change on physical, mental, and community health; Source: US Climate Resilience Toolkit



Recreation opportunities may also increase. Increased average temperatures create the potential for increased participation in spring and fall recreation (e.g., biking, golfing) and summer water-based recreation.

Changes in Pennsylvania's ecosystems will affect the species living within them. As habitats shift for various species, there will also be an increase in suitable habitat for species at the northern extent of their range in Pennsylvania along with habitat loss at the southern end of their range. With changes in timing of migration and blooming, these changes in habitat range may have negative impacts.

Predicting and building the capacity to make use of these changes may prove beneficial to many.

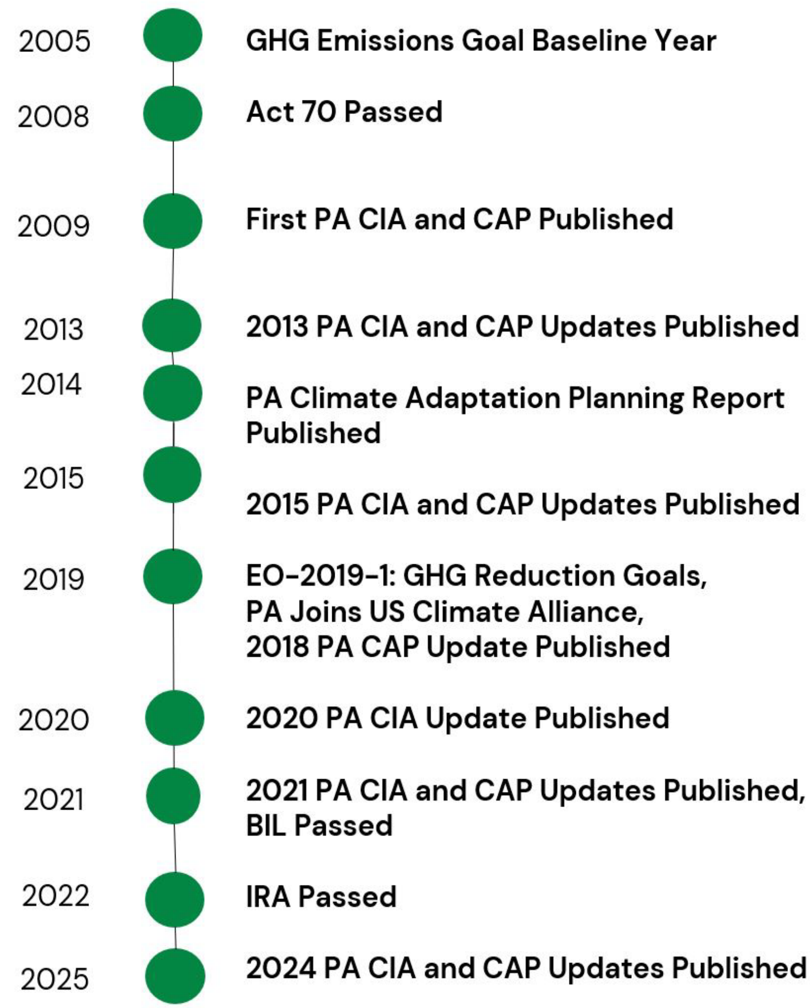
History of Climate Action Planning in Pennsylvania

Pennsylvania has a strong history of climate action planning, beginning with the Pennsylvania Climate Change Act (Act 70) of 2008 and continuing to this day and beyond with this 2024 Plan. Beyond its statewide planning efforts, the Commonwealth has encouraged more local jurisdictions to engage in more community-level climate planning with the launch of the Local Climate Action Program (LCAP) in 2019, in line with recommendations included in the 2019 iteration of the Pennsylvania CAP. Details on these efforts are below.

Pennsylvania Climate Change Act and Emissions Reduction Goals

The Pennsylvania Climate Change Act of 2008 requires the DEP to compile an annual GHG inventory for Pennsylvania's GHG emissions, to develop a voluntary GHG registry, and to develop a CAP and CIA and update them at a regular frequency. Act 70 also

Figure 5. Pennsylvania Climate Action Timeline



established the CCAC to advise DEP during the development of the IA and CAP. Working with the CCAC, DEP has prepared a series of CAPs and GHG mitigation strategies since the act was passed.

In 2019, Pennsylvania joined the United States Climate Alliance ("US Climate Alliance"), a bipartisan coalition of governors aiming to advance high-impact climate action. Emissions reduction goals of the US Climate Alliance include:

- Reducing collective net GHG emissions at least 26-28% by 2025 and 50-52% by 2030, both below 2005 levels.
- Collectively achieving overall net zero GHG emissions as soon as practicable, and no later than 2050.[4]

This updated 2024 CAP aligns with these emissions reduction goals and includes a prioritized set of GHG reduction strategies that, if implemented successfully, could help achieve these goals. This 2024 Plan also recognizes and maps out flexible strategies and pathways for adapting to the impacts of climate change in Pennsylvania, building directly on the 2024 CIA.

Local Climate Action Program

Following the 2019 iteration of the Pennsylvania CAP, DEP launched LCAP to help local governments lead by example on critical climate change actions. LCAP provides free technical and personnel assistance to local governments for planning efforts to reduce GHG emissions and address climate change. As of 2023, LCAP has trained 64 cities townships, boroughs, counties, and regional organizations, representing approximately 440 municipalities across the Commonwealth.

Following the development of their CAPs, local jurisdictions have begun taking mitigation actions. This 2024 Plan was informed by successes and lessons learned by local jurisdictions in their LCAP the planning and implementation processes. Now administered by the Penn State Sustainability Institute, LCAP has been a crucial program for connecting state-level climate planning and goals with local leaders and jurisdictions to catalyze climate action.

Efforts of Other Pennsylvania Agencies

Action on climate change requires the work of many parties, within and outside of DEP. Other agencies in Pennsylvania have been taking action to reduce GHG emissions and build resilience in the Commonwealth, and the strategies in this CAP aim to align with these efforts, a sampling of which are summarized below. This plan acknowledges and builds on the ongoing coordination on climate action between DEP and other state agencies like DNCR, PennDOT, Department of Agriculture (PDA), Department of Health (PA DOH), and more.

DCNR's Adaptation and Mitigation Plan

The DCNR Climate Change Adaptation and Mitigation Plan aims to utilize the Department's 2.2 million acres of state forests, 124 state parks, grants from the Community Conservation Partnership Program, research and data from the Geologic Survey, and any other resources necessary within the Department to mitigate

[4] "About: U.S. Climate Alliance." n.d. https://usclimatealliance.org/about/.

atmospheric carbon as well as ensure that the Commonwealth's public lands remain resilient and able to adapt to climate change. DCNR seeks to be a leader in climate-smart land management and green infrastructure development. The plan provides a look at current and future climate change impacts, and the actions taken by DCNR to address these vulnerabilities. This plan will continue to evolve as more is understood about mitigating climate change's effects and best practices for adaptation strategies.

Additionally, DCNR is also working on implementing the following:

- **2022-23 Tree Plantings and Tree Equity:** DCNR planted 24,397 trees through the buffer implementation and lawn conversions covering over 139 acres of land. An additional 2.8 million trees were distributed through the Bureau of Forestry Nursery, and over 2700 trees were planted through TreeVitalize. These tree plantings and lawn conversions will result in a projected 37,800 tons of carbon sequestered. Additionally, tree canopy is inequitably distributed across the Commonwealth, with investments often delineated by income and race. Racist land use policies have resulted in far less tree coverage in low-income and BIPOC (Black, Indigenous, and People of Color) communities, which also bear the greatest burdens related to climate change and its harmful impacts. DCNR is advancing tree equity to ensure that there is a balance of trees throughout all Pennsylvania communities to achieve the full health, social, economic, and climate benefits of tree equity.
- **GESA Savings:** DCNR has been implementing Guaranteed Energy Savings Act (GESA) actions across the state through three phases to increase energy efficiencies and reduce energy costs; two phases have been implemented with the Department realizing $30.7 million in guaranteed utility cost savings over 20 years.
- **Investment in Minoritized, Low-Wealth Communities:** In addition to tree planting, DCNR is supporting outdoor recreation and conservation investments in underserved and under-resourced communities. These investments offer a myriad of opportunities to advance public health, improve quality of life, support local tax bases and economic vitality, strengthen accessibility, and create experiential and educational opportunities for all, including youth and young adults.
- **Sustainable Forest Management and Forest Conservation:** 70% of Pennsylvania forested lands are owned privately. DCNR, through its service foresters and watershed and forestry team, offers consultation and expertise to support sustainable stewardship and best forestry management practices on private lands and funding that expands forest buffers, tree plantings, and forest canopy.
- **Transportation:** DCNR plans to convert 25% of passenger vehicles (sedans, SUVs, vans) to either EVs or plug-in hybrid electric vehicles (PHEVs). 62 additional vehicles needed to be procured. To date, DCNR has procured 35 EVs and PHEVs, including sedans, vans, and e-cycles. DCNR has also installed 48 EV charging stations at state park and forest locations as of September 2024. An additional four public charging stations are in various stages of construction and design.
- **Renewable energy:** By 2030, DCNR will produce or purchase 100% of its electricity from renewable sources. DCNR has also installed 34 solar installations, producing 5.1 thousand kWh and resulting in $560,746 in annual energy savings. DCNR has also

completed 30 solar installations, which are capable of producing up to 3.1 million kWh per year resulting in $469,000 in annual energy savings.

PennDOT Vulnerability Study

In 2017, PennDOT completed an Extreme Weather Vulnerability Study as part of a multiphase effort to better anticipate the consequences and potential impacts of extreme weather events. The study focused on the evaluation of historic vulnerabilities, development of a framework for addressing climate change impacts, and an initial assessment of risks and priorities. The study's analyses and mapping products were focused primarily on the flooding impacts on state-owned roads and bridges. PennDOT continues to monitor historic flooding and has integrated the risk assessment procedures into the selection of projects under the PROTECT funding program.

PennDOT Pilot Study for Addressing Climate Change in Design Process

In 2020, PennDOT completed a resiliency pilot study to identify potential data, methods, and procedures that could be integrated into PennDOT's current design process to address climate change impacts. Key components of the study included data exploration, methodology development, and drawing from national research efforts. By integrating climate resilience considerations into PennDOT's design practices, the study aimed to enhance transportation asset durability and adaptability in the face of changing weather patterns. This study has supported PennDOT's current initiatives to update their Design Manual (DM2) to include comprehensive design checklists that guide engineers in evaluating alternative scenarios and assessing adaptation strategies for locations at risk of extreme weather events.

PennDOT Pennsylvania Carbon Reduction Strategy (CRS)

In November 2023, PennDOT released the Pennsylvania Carbon Reduction Strategy in support of the Federal Carbon Reduction Program (CRP), as established under the 2021 BIL. The CRP provides funds for projects designed to reduce carbon emissions from on-road highway sources, PA is expected to receive approximately 264 million through fiscal year 2026 under the CRP. The Carbon Reduction Strategy provides PennDOT with a guide and action plan for implementing the CRP and other carbon reduction activities. It aims to:

- Publicly share information on carbon reduction initiatives and funding;
- Support decision-making;
- Promote coordination;
- Guide project identification and prioritization; and,
- Provide a path forward on broader-level policies and actions to reduce carbon emissions.

A more in-depth guide for determining what projects are eligible for the CRP can be found here: Carbon Reduction Eligibility Examples.

PennDOT and regional planning partners throughout the state have already programmed projects using CRP funds. These projects include traffic flow improvements, multi-modal investments, energy-efficient lighting, and electric vehicle infrastructure.

More information on PennDOT's carbon reduction efforts can be found on PennDOT's Carbon Reduction Webpage.

Pennsylvania Emergency Management Agency (PEMA) State Hazard Mitigation Plan

PEMA's Hazard Mitigation Plan was updated in 2023. The updated plan acknowledges the mandate to consider the impact of climate change adaptation throughout the document and maximizes the efforts and collaboration of state agencies and stakeholders already doing State Hazard mitigation work. There are five mitigation goals around which the plan was built:

- Protect lives, property, environmental quality, and resources of the Commonwealth, including high-risk properties.
- Enhance consistent coordination, collaboration, and communications among interested parties.
- Provide a framework for active hazard mitigation planning and implementation.
- Build legislative and other organizational support and leverage funding for mitigation efforts.
- Increase awareness, understanding, and preparedness across all sectors.

The 2023 HMP adds two new objectives to address Climate Change. Under Goal 1, the following objective is added: Implement hazard mitigation projects that address Climate Change. This objective focuses on specific physical projects that address Climate Change such as the deployment of EV infrastructure, implementing clean energy generation projects, improving electric grid resilience, and reducing the impact of urban heat islands.

Under Goal 3, the following objective is added: Integrate Climate Change into hazard mitigation planning. This objective focuses on integrating ongoing Climate Change planning efforts such as planning for microgrids, mitigating greenhouse gases, and addressing climate impacts adaptation priorities into hazard mitigation planning.

In Pennsylvania, a total of 33 unique hazardous events were identified in 2023 and further organized into two groups: Human-caused and Natural-caused. Hazards are compared and ranked according to six Risk Assessment Categories which notably include Climate Change as an added category in the 2023 plan. Key hazards such as drought, wildfires, extreme temperatures, tornados, hurricanes, flooding, invasive species, and disease, are expected to be exacerbated or impacted by climate change, and the plan recommends that a more robust assessment of climate change impacts be included in the future occurrences section of each hazard profile.

DOH State Health Improvement Plan & Environmental Justice Strategic Plan

PA DOH is working to protect Pennsylvanians from the health impacts of a changing climate.

The latest version of the State Health Improvement Plan includes an environmental health goal, with objectives related to improving air quality, decreasing heat-related hospitalizations, and testing more children for lead. These objectives will be met by various capacity building, surveillance, and outreach strategies to improve environmental health in Pennsylvania.

PA DOH also has an Environmental Justice Strategic Plan which lays out internal and external strategies on how the department intends to commit to those living in EJ areas and improve their health and representation in the department's work. Staff from the Division of Environmental Health Epidemiology, Bureau of Emergency Preparedness and Response, Office of Health Equity, and the Policy Office are leading these efforts, including developing an equity-informed climate work plan which addresses how a changing climate is affecting health. PA DOH has published a document detailing how different changing climate threats are impacting public health. This document also provides information on departmental programs that are working to address these issues and identifies disproportionately affected populations. Part of the work plan includes strengthening our coalition of partners working in the climate space.

Legislative and Funding Context

Since the last CAP was released in 2021, there has been unprecedented action at the federal level to increase funding for renewable energy, energy efficiency, and emerging clean energy technologies. These efforts have been funded mainly through the IIJA—commonly known as the BIL—and the IRA. Other programs such as the FEMA Building Resilient Infrastructure in Communities grant (BRIC) program are also important sources of funding to implement the strategies in this CAP. Many of these programs emphasize or require support to disadvantaged communities, aligning well with the equity focus of this CAP.

Infrastructure Investment and Jobs Act

The IIJA provides $1.2 trillion for transportation and infrastructure spending, with $550 billion allocated for new investments and programs promoting sustainable, resilient, and just economic growth. Programs through which Pennsylvania will receive funds from the IIJA include:

Table 5. IIJA Program Summary

Program	Value
National Electric Vehicle Infrastructure Formula Program	$172 million for Pennsylvania
Regional Clean Hydrogen Hubs	$1.68 Billion for Pennsylvania Connected Hubs
Energy Improvement in Rural and Remote Areas	$300,000 – $100 million per project
Grid Resilience and innovation Partnerships Program	$120 Million to Pennsylvania Recipients
State Energy Program	$14 million
Energy Efficiency and Conservation Block Grant	$3 million to state, $9.8 million for local governments
Energy Efficiency Revolving Loan Fund	$3.3 million
Preventing Outages and Enhancing the Resilience of the Electric Grid	$40 million
Energy Auditors Training Program	$2 million

Resilient and Efficient Codes Implementation/Building Codes Assistance and Training	$3 million received by DEP
Grants for Energy Efficiency Improvements and Renewable Energy Improvements at Public School Facilities	$7 million to Pennsylvania in first funding round
Replacement of Existing School Buses with Clean and Zero Emission School Buses	$5 billion nationwide
Weatherization Assistance Program Enhancement and Innovation	$2 million

More information on IIJA programs is available in Appendix C section on the Infrastructure Investment and Jobs Act.

Inflation Reduction Act

The IRA is the largest ever federal investment in clean energy and climate. It is projected to fund projects that will lead to a 32-40% reduction in emissions below 2005 levels in the Unites States. $369 billion is allocated for climate and energy investment tax credits directly available to individual and business taxpayers as well as rebate programs. These tax credits cover:

- Clean energy; including but not limited to wind and solar, energy storage, and nuclear
- Residential rooftop solar and energy efficiency
- EV
- Sustainable aviation fuels
- Clean energy manufacturing
- Clean hydrogen and CCUS
- Clean energy workforce development

The IRA also includes several grant funding opportunities that Pennsylvania can participate in to fund the strategies in this CAP.

Table 6. IRA Program Summary

Program	Value
Greenhouse Gas Reduction Fund	$27 billion
National Clean Investment Fund (GHGRF)	*$14 billion*
Clean Communities Accelerator (GHGRF)	*$6 billion*
Solar for All (GHGRF)	*$7 billion nationally, $156 million to DEP*
Climate Pollution Reduction Grants (Planning)	$6 million to DEP (state planning) and regional planning bodies of Philadelphia, Pittsburgh, and Lehigh Valley metropolitan areas.
Climate Pollution Reduction Grants (Implementation)	Competitive grants of $2-$500 million per project
Home Energy Efficiency and Electrification Rebate Programs (HER and HEAR)	$260 Million formula for Pennsylvania
Assistance for Latest and Zero Building Energy Code Adoption	$8.7 million formula for Pennsylvania $670 million competitive grants
Low Emissions Electricity Program	$17 million per partnership

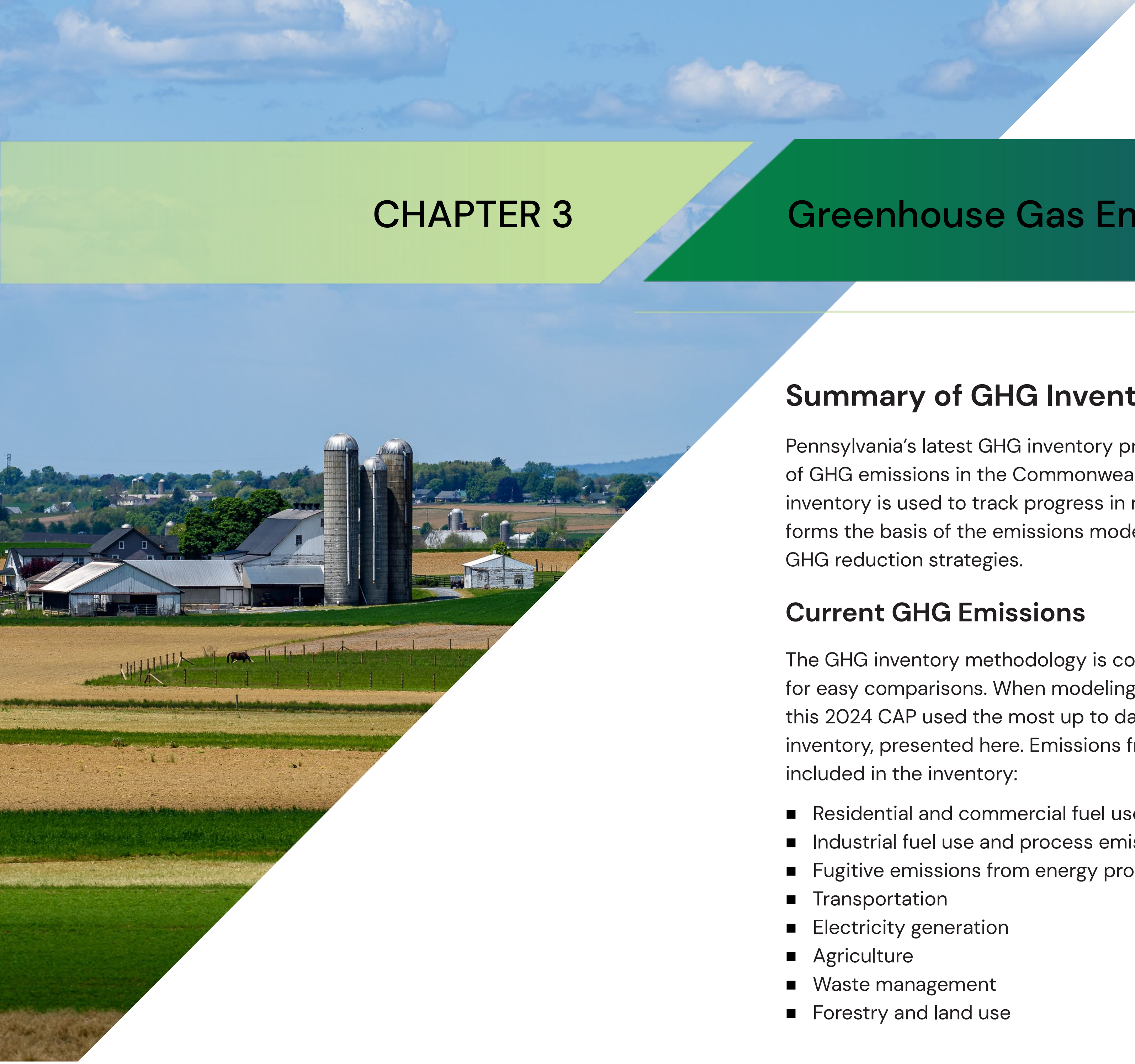
State-Based Home Energy Efficiency Contractor Training Grants	$200 million

More information on IRA programs is available in Appendix C section Inflation Reduction Act.

Building Resilient Infrastructure in Communities

FEMA's BRIC program provides funds to reduce the overall risk to populations and infrastructure from future hazard events. FEMA identified 24 projects from Pennsylvania, with total funding of approximately $85 million for further review from FY 2022 applications, the next step in the process for receiving funding.

More information on BRIC is available in Appendix C Building Resilient Infrastructure in Communities.



CHAPTER 3

Greenhouse Gas Emissions

Summary of GHG Inventory

Pennsylvania's latest GHG inventory provides a holistic accounting of GHG emissions in the Commonwealth from 2000 to 2020. This inventory is used to track progress in reducing GHGs over time and forms the basis of the emissions modeling scenarios and proposed GHG reduction strategies.

Current GHG Emissions

The GHG inventory methodology is consistent across years to allow for easy comparisons. When modeling GHG mitigation strategies, this 2024 CAP used the most up to date Pennsylvania GHG inventory, presented here. Emissions from the following sectors are included in the inventory:

- Residential and commercial fuel use
- Industrial fuel use and process emissions
- Fugitive emissions from energy production
- Transportation
- Electricity generation
- Agriculture
- Waste management
- Forestry and land use

Overall GHG Emission Trends

As reported in the latest Pennsylvania State GHG inventory, total statewide gross emissions in 2020 were 238.74 $MMTCO_2e$. Gross emissions do not account for the carbon sequestered by the land use, land use change, and forestry (LULUCF) sector, which sequestered 24.79 $MMTCO_2e$ in 2020, resulting in net GHG emissions of 213.94 $MMTCO_2e$. Emissions in 2020 are 25.9% lower than the 2005 baseline emissions of 288.63 $MMTCO_2e$.

Emissions have declined across most sectors, except for fugitive emissions from energy production (natural gas and oil systems), industrial emissions (both fuel consumption and process emissions), and agriculture emissions (resulting from agricultural soil management, liming, and urea fertilization). As of 2020, the three largest sources of emissions in Pennsylvania are:

- Electricity Generation (29% of gross emissions)
- Transportation Fuel Consumption (22% of gross emissions)
- Industrial Emissions (19% of gross emissions)

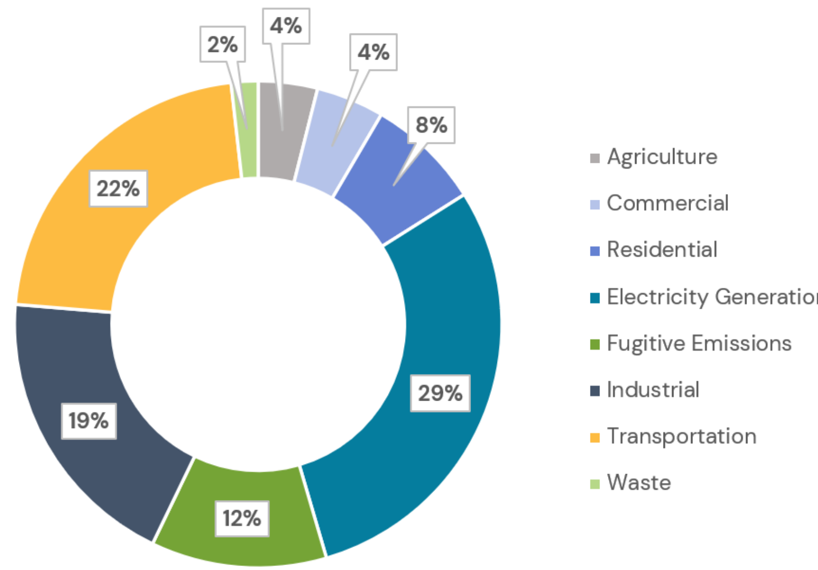
COVID-19 Pandemic Impacts

Though Pennsylvania has reduced emissions by nearly 26% from 2005 levels (the Commonwealth's 2025 GHG reduction goal), 2020 GHG emission data were skewed by the COVID-19 pandemic, resulting in some unexpected major emissions decreases, particularly in the transportation sector. Recent energy generation, use, and emissions data point to potential increases in the emissions since 2020, as the economy has rebounded from the pandemic.

Sector Trends

Electricity generation, direct fuel consumption, fugitive emissions from energy production, and industrial process emissions account for 94% of Pennsylvania's gross emissions. Transportation fuel consumption is 22% of total emissions. Industrial emissions include emissions from direct fuel use and industrial processes, accounting for 14% and 5% of total emissions, respectively. Fugitive emissions from energy production account for 12%. Recent trends from each sector are discussed on the following pages.

Figure 6. Pennsylvania 2020 GHG Emissions by Sector

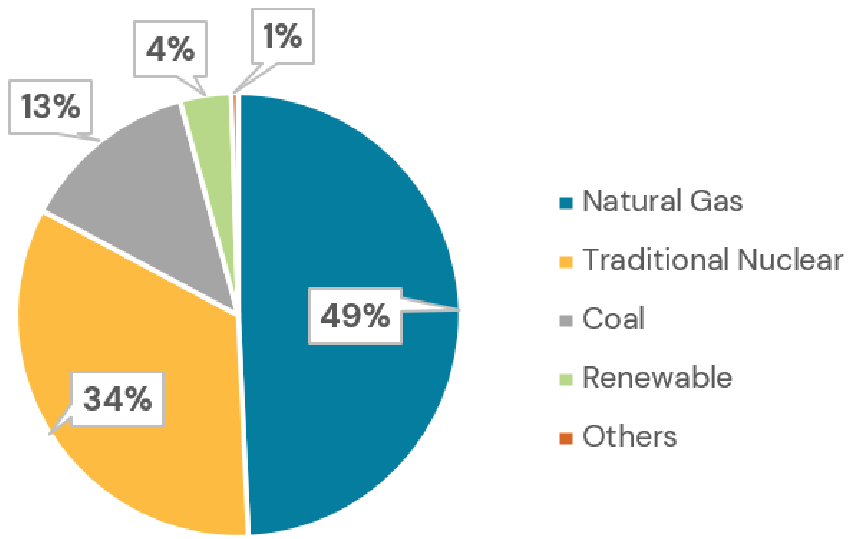


Electricity Generation

Emissions from electricity generation decreased 10.4% from 2019 to 2020 and 44.4% from 2005 to 2020. This is mainly a result of coal generation being replaced by natural gas generation (and to a smaller extent renewable energy sources like wind and solar) and energy efficiency improvements, due in part to Act 129. Coal-based electricity generation decreased from 60% of Pennsylvania's total electricity in 2005 to 10% in 2020. In 2020, natural gas was the largest source of electricity generated in Pennsylvania, providing 49.3% of all electricity, surpassing nuclear generation in 2019.

Figure 8 shows the breakdown of electricity generated in Pennsylvania by fuel type in 2020. In 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 and fuel oil.

Figure 7. Electricity Generation by Fuel Type, 2020



Industrial emissions made up 19% of Pennsylvania's net emissions in 2020, with the largest contribution stemming from direct fuel consumption with 32.89 MMTCO_2e. Process emissions generated 12.86 MMTCO_2e in 2020.

The Power of Fuel-Switching

Coal-based electricity generation decreased from 60% of Pennsylvania's total electricity in 2005 to 10% in 2020. Much of this generation has moved to natural gas and has resulted in a 44.4% reduction in electricity generation-based emissions from 2005 to 2020. Generation capacity increased by 17% from 53,661 GWh in 2005 to 62,529 GWh in 2050.

Fugitive emissions from energy production contributed to about 27.82 MMTCO_2e in 2020. Most of these emissions (about 58%) were from natural gas and oil systems while the remainder were from coal mining. Natural gas and oil systems include fugitive emissions from production, transmission, and storage of natural gas and petroleum products. **Fugitive energy emissions have increased 17.2% since 2005.** Coal mining emissions have remained relatively steady while natural gas and oil systems emissions have increased, coinciding with the rise in natural gas use in electricity generation.

Including fugitive emissions from energy production, industrial emissions have **increased by 5.1% from 2005 level,** coinciding with an increase in manufacturing Gross State Product (GSP) of

49% from 2007 to 2022.[5] Pennsylvania's economy largely consists of industrial activity compared to other states. Industries in Pennsylvania with high levels of emissions include cement manufacturing, iron and steel production, and the utilization of ozone-depleting substance (ODS) substitutes.

Residential and Commercial Fuel Use

Residential and commercial emissions from fuel use (i.e., onsite fuel combustion, not electricity consumption) come from the direct use of fuels in homes, businesses, institutional facilities, and other large buildings. **Emissions from the residential and commercial sectors have decreased 25.2% and 17.1% respectively, since 2005,** a likely result of the following factors:

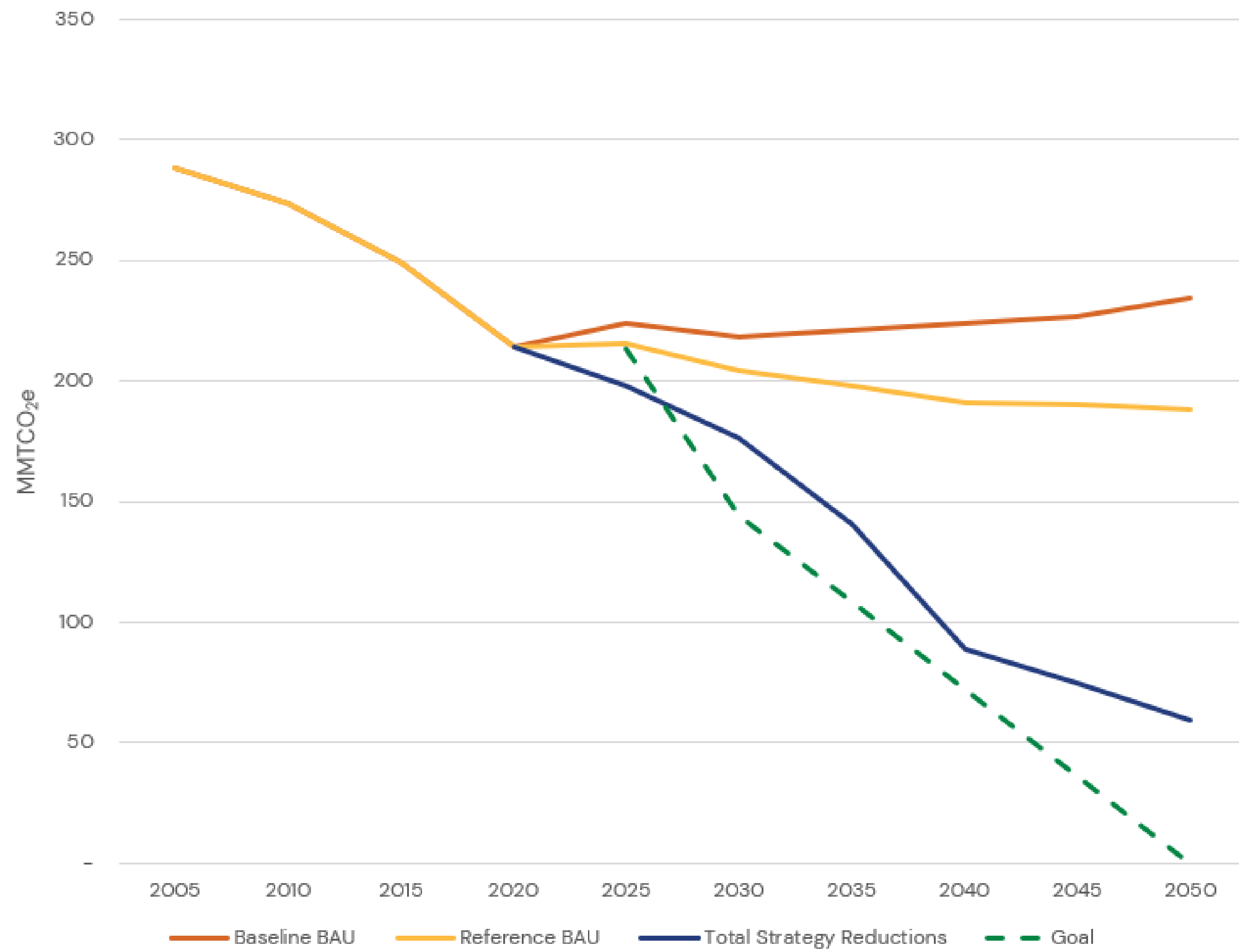
- Fuel switching to lower-emitting fuels for heating
- Energy efficiency improvements resulting from Act 129 (which requires efficiency improvements that also impact fuel consumption, on top of required reductions in electricity use)
- Technology improvements over time (e.g., ENERGY STAR certified products)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

Business-As-Usual Scenarios

DEP developed two business-as-usual (BAU) scenarios for this CAP to get an understanding of how Pennsylvania's GHG emissions might look in the future. The **Baseline BAU** scenario is strictly a BAU scenario that reflects future emissions if current policies are held constant and no new policies are introduced to reduce GHG emissions. The **Reference BAU** scenario is a more probable scenario and includes federal policies such as the IRA in future emissions projections. These two BAU scenarios are historically identical and begin to diverge at the baseline year of 2021. Both BAU scenarios serve as the basis for which emission reduction strategies are compared against. Both BAU scenarios show Pennsylvania's net emissions, including both sources of emissions and emissions that are sequestered via land use and carbon sinks. Figure 8 on the following page shows the differences in net emissions between the Baseline and Reference BAUs.

[5] "Pennsylvania Manufacturing Industry Report 2023." 2023. https://nepirc.com/paindustryreport2023/.

Figure 8. Baseline vs Reference BAU Emissions



Key differences between the Baseline and Reference BAUs

The Reference BAU includes additional effects of the IRA and IIJA. The inclusion of these policies leads to greater emissions reductions by 2050. For example, the Reference BAU scenario includes:

- Greater emissions reductions due to decreased electricity use and emissions in residential and commercial buildings.
- Lower transportation emissions due to greater EV penetration.
- A smaller increase in projected industrial emissions due to lower-carbon energy input for industrial processes.
- Lower carbon intensity from the electricity grid.

Baseline BAU Scenario

The Baseline BAU scenario uses the 2020 Pennsylvania GHG inventory data as the base year and projects GHG emissions through 2050 under GHG reduction policies currently in place, exclusive of the IIJA and IRA. The Baseline BAU is a benchmark for Pennsylvania's GHG reduction planning, providing emissions estimates that can be compared against emissions from the Reference BAU scenario and from the strategies developed in this CAP. In the Baseline BAU scenario, Pennsylvania's net emissions are projected to be 234.47 $MMTCO_2e$ in 2050, including carbon sinks. This represents a 19% decrease in net emissions from 2005. 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).

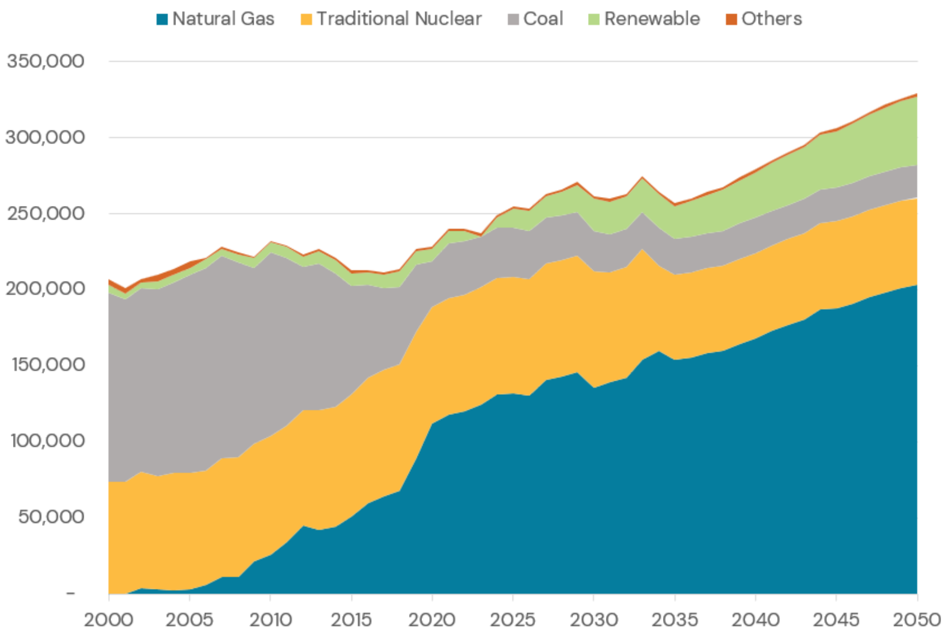
Under the Baseline BAU scenario, Pennsylvania will not achieve its 2025 reduction goal and it will be significantly distant from reaching net zero by 2050. Net emissions for 2025 are projected to be 248.8 $MMTCO_2e$, a 21.7% reduction from 2005 (3.3% off from the 2025 goal). Gross emissions for 2025 are projected to be 224.2 $MMTCO_2e$, a 22.3% reduction from 2005. Beyond 2025, the Baseline BAU shows slowing GHG emission reductions and even small increases in some years. Table 3 shows a breakdown of net emissions by sector for the Baseline BAU.

Table 7. Baseline BAU Net Emissions by Sector ($MMTCO_2e$)

Sector	2005	2020	2025	2030	2050	% change 2005–2050
Electricity Generation	126.31	70.22	70.02	65.35	80.02	**-37%**
Residential Fuel Use	24.25	18.14	19.61	19.06	17.28	**-29%**
Commercial Fuel Use	12.98	10.76	11.74	11.60	11.38	**-12%**
Industrial (Process + Fuel Use)	46.23	45.74	54.25	55.74	59.82	**29%**
Fugitive Emissions	23.74	27.82	20.95	21.04	22.68	**-4%**
Transportation	70.84	52.25	60.12	57.70	54.63	**-23%**
Agriculture	8.23	9.37	7.22	7.21	7.20	**-13%**
Waste	5.35	4.25	4.90	5.17	6.06	**13%**
Gross Emissions	**317.92**	**238.55**	**248.80**	**242.87**	**259.08**	**-19%**
Carbon Sinks (LULUCF)	(29.29)	(24.60)	(24.60)	(24.60)	(24.60)	**-16%**
Net Emissions	**288.63**	**213.94**	**224.20**	**218.26**	**234.47**	**-19%**

The projected decrease in statewide emissions by 2050 from 2005 levels is driven primarily by the decrease in emissions from electricity generation which are projected to decrease sharply, by 48%, between 2005 and 2030 as a result of switching from coal to gas generation due to economic and market factors (Figure 9). Total electricity generation associated with in-state consumption is projected to increase from 228,327 GWh in 2020 to 310,591 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. By 2050, emissions from electricity generation are projected to be just over 80 $MMTCO_2e$ in 2050, a 37% decrease from 2005 levels.

Figure 9. Baseline BAU Generation Mix Over Time



As of 2019, 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 in the Baseline BAU in future years is a result of waste coal supported by the Alternative Energy Portfolio Standard (AEPS) Tier II requirement. Under the Baseline BAU scenario, natural gas is expected to continue growing as the primary fuel source for electricity generation; by 2050, it will produce over 65% of Pennsylvania's electricity. Nuclear generation remains steady with a significant drop between 2030 and 2040 then remains steady through 2050, making up 18% of the state's electricity generation. Figure 9 shows the historical and projected fuel mix for electricity generated in Pennsylvania from 2000 through 2050 (Baseline BAU scenario). In Figure 9, 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.

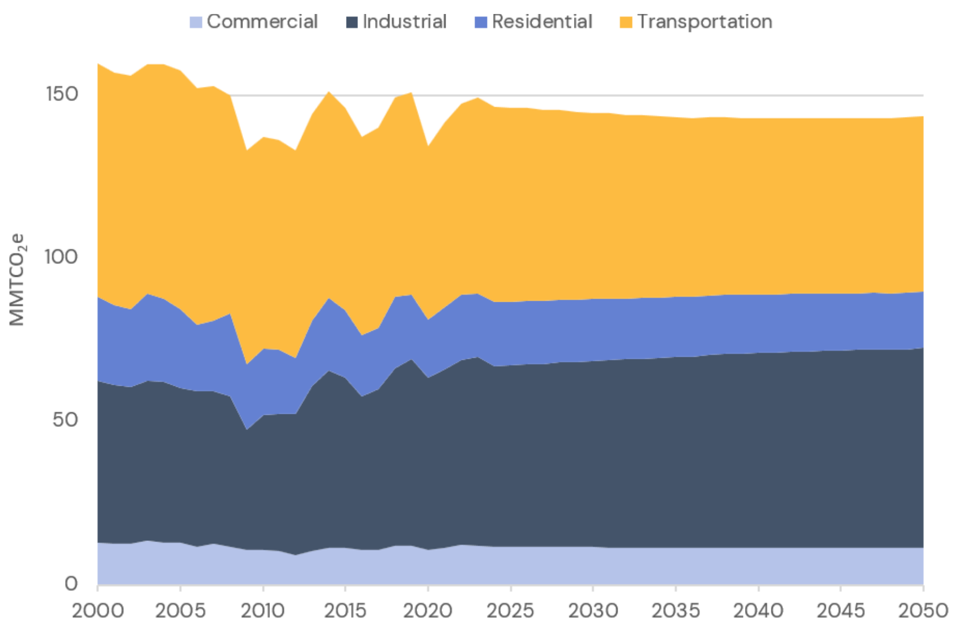
Emissions from direct fuel consumption for residential, commercial, industrial, and transportation uses, which together make up the majority of emissions in Pennsylvania (53% in 2020), are projected to decrease by about 2.4%, from 140 $MMTCO_2e$ in 2005 to 137 $MMTCO_2e$ in 2050.

Emissions from fuel consumption for transportation and residential uses each decrease by around 25% through 2050 when compared to 2005. These reductions are likely a result of improved energy efficiency through the 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 32.05 $MMTCO_2e$ in 2005 to 53.42 $MMTCO_2e$ in 2050. The increase is driven mainly by economic growth indicators in the Annual Energy Outlook (AEO) Reference Case (2020). Figure 10 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 baseline BAU totals, because that would result in double-counting the emissions from electricity production included.

Fugitive emissions from energy production, which includes methane emissions from coal mining and natural gas and oil systems, are projected to decrease from around 28 $MMTCO_2e$ in 2020 to almost 23 $MMTCO_2e$ in 2050. This is primarily driven by the shift away from coal production (driven by market preferences), and fugitive emissions from natural gas production remaining constant (see Figure 10). 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 55% 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. Industrial emissions from 18 of these gases, including HFCs, PFCs, and SF6, 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.

Figure 10. Emissions from direct fuel consumption (non-electricity) by sector – Baseline BAU, 2000–2050



Agricultural emissions decrease by about 13%, from 8.2 $MMTCO_2e$ in 2005 to 7.2 $MMTCO_2e$ in 2050. Waste emissions remain fairly constant, decreasing slightly from 5.4 $MMTCO_2e$ in 2005 to 4 $MMTCO_2e$ in 2020 before increasing to 6.0 $MMTCO_2e$ in 2050 because of increases in municipal solid waste and wastewater emissions.

Reference BAU Scenario

The Reference BAU scenario uses the 2020 data in the latest Pennsylvania GHG inventory as the base year and projects GHG emissions through 2050 under GHG reduction policies in place inclusive of the IIJA and IRA. The Reference BAU is another benchmark for Pennsylvania's GHG reduction planning, providing emissions estimates that can be compared against emissions from the Baseline BAU scenario and from the strategies developed in this

CAP. Table 8 shows Reference BAU emissions estimates by sector from 2020 through 2050. In the Reference BAU scenario, Pennsylvania's net emissions are projected to be 188.08 $MMTCO_2e$ in 2050 including carbon sinks. This represents **a 35% decrease in emissions from 2005**. 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 Reference BAU scenario, Pennsylvania will achieve its 2025 reduction goal but will be significantly off from achieving net zero by 2050. Without the implementation of the IRA/IIJA, Pennsylvania would not reach its 2025 goals (BAU Baseline). Net emissions for 2025 are projected to be 215 $MMTCO_2e$, a 25% reduction from 2005. Beyond 2025, the Reference BAU emission reductions are projected to slow down over time, and even increase slightly in some years. Even with the impacts of the IIJA and IRA, action will still be needed for Pennsylvania to meet its emissions reduction goals.

Emissions from electricity generation are projected to be 40 $MMTCO_2e$ in 2050, a 68% decrease from 126 $MMTCO_2e$ 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 50%, between 2005 and 2030 as a result of switching from coal to gas generation due to economic and market factors. Additional changes in generation from higher-emitting to lower-emitting sources before 2030 are driven partly by the AEPS.

Table 8. Reference BAU Net Emissions by Sector ($MMTCO_2e$)

Sector	2005	2020	2025	2030	2050	% change 2005–2050
Electricity Generation	126.31	70.22	70.02	62.82	40.32	**-68%**
Residential Fuel Use	24.25	18.14	18.84	17.44	15.23	**-37%**
Commercial Fuel Use	12.98	10.76	11.14	10.64	10.38	**-20%**
Industrial (Process + Fuel Use)	46.23	45.74	53.96	53.92	57.04	**23%**
Fugitive Emissions	23.74	27.82	20.95	21.04	22.68	**-4%**
Transportation	70.84	52.25	53.16	51.04	53.95	**-24%**
Agriculture	8.23	9.37	7.22	7.21	7.20	**-13%**
Waste	5.35	4.25	4.90	5.17	6.06	**13%**
Gross Emissions	**317.92**	**238.55**	**240.17**	**229.29**	**212.87**	**-33%**
Carbon Sinks (LULUCF)	(29.29)	(24.60)	(24.79)	(24.79)	(24.79)	**-15%**
Net Emissions	**288.63**	**213.94**	**215.38**	**204.49**	**188.08**	**-35%**

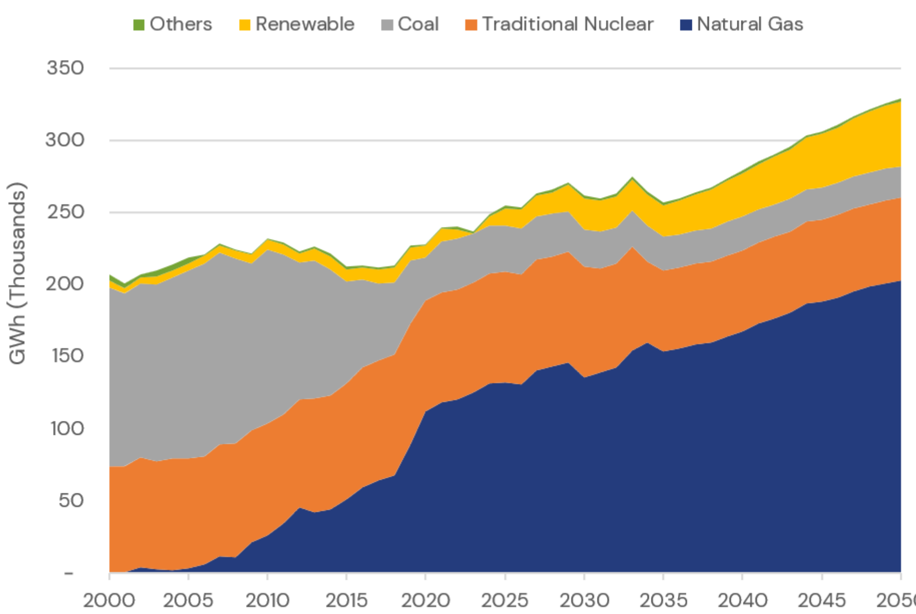
Unlike in the Baseline BAU, total electricity generation associated with in-state consumption in the Baseline BAU is projected to decrease from 228,327 GWh in 2020 to 208,909 GWh in 2050 due to increases in energy efficiency in residential, commercial, industrial, and transportation sectors as a result of Act 129, IIJA, and IRA efforts.

As of 2019, natural gas has overtaken nuclear as the largest fuel source for electricity generation in Pennsylvania and continues to replace coal generation. Coal generation is projected to fall and hold constant from 2035 onwards in the Reference BAU scenario. Under this scenario, natural gas is still expected to be the primary fuel source for electricity generation; by 2050, it will produce 46% of Pennsylvania's electricity. Nuclear generation peaks in the late 2020s, and steadily declines until 2050, making up 26% of the state's electricity generation. Renewable electricity sources like wind and solar make up 22% of the state's electricity generation in 2050. Figure 11 shows the historical and projected fuel mix for electricity generated in Pennsylvania from 2000 through 2050 (baseline BAU scenario). In Figure 11, 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.

Emissions from direct fuel consumption for residential, commercial, industrial, and transportation uses, which together make up the majority of emissions in Pennsylvania (53% in 2020), are projected to decrease by 7%, from 140 MMTCO2e in 2005 to 130 MMTCO2e in 2050.

Emissions from fuel consumption for transportation are projected to decrease by 24% in 2050 when compared to 2005 levels, while residential fuel consumption emissions are projected to decrease by 37% in 2050 for the same timeframe. These reductions are likely a result of improved efficiency of transportation fuels (e.g., motor gasoline), which will result in less fuel used to meet demand. IIJA and IRA will also provide another force to further reduce emissions

Figure 11. Reference BAU Electricity Generation Mix Over Time

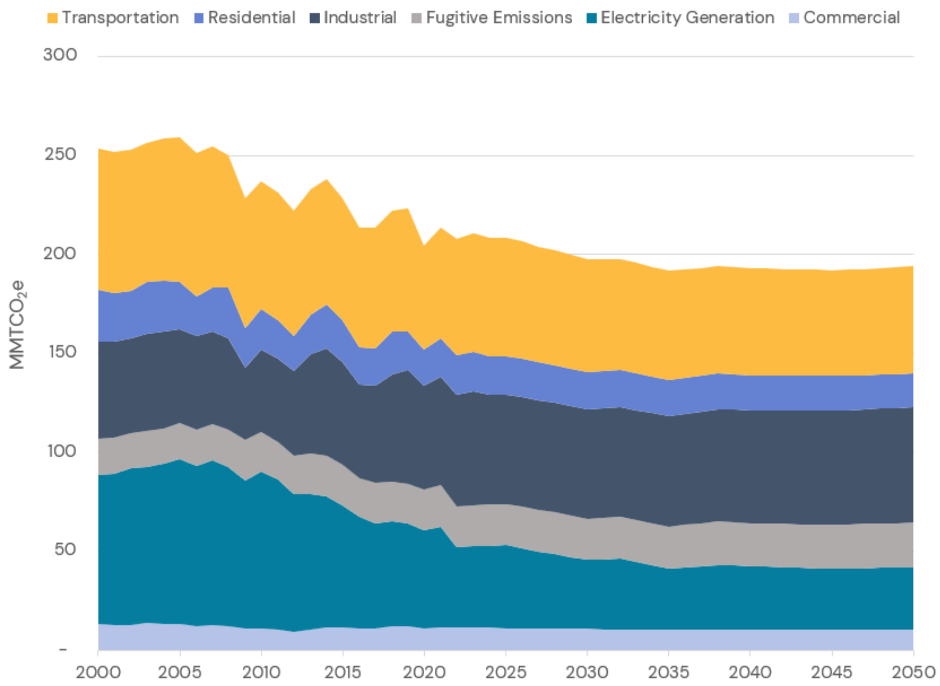


in the Reference BAU scenario compared to the baseline BAU scenario. Industrial emissions from direct fuel consumption are projected to increase from 32.05 $MMTCO_2e$ in 2005 to 50.64 $MMTCO_2e$ in 2050. The increase is driven mainly by economic growth indicators in the AEO Reference Case (2020). The IIJA and IRA do mitigate the emissions in comparison to the Baseline case.

Figure 1213 shows projected emissions from direct fuel consumption by sector through 2050. In line with the GHG accounting approach in the state inventory, emissions from electricity consumption are not included in the baseline BAU totals, because that would result in double-counting the emissions from electricity production included.

Similarly, to the Baseline BAU, fugitive emissions from energy production, which includes methane emissions from coal mining and natural gas and oil systems, are projected to decrease from 27 $MMTCO_2e$ in 2020 to 23 $MMTCO_2e$ in 2050. This is primarily driven by market and economic drivers reducing demand and therefore production of coal. At the same time, natural gas production has increased, but fugitive emissions from natural gas production remain relatively constant (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 55% from 2005 levels by 2050. As described

Figure 12. Emissions from Direct Fuel Consumption by Sector - Reference BAU, 2000–2050



in the Baseline BAU, this is primarily driven by the decrease in emissions from high global warming potential gases resulting from the expected phaseout of HFCs. Similarly, agricultural and waste emissions increase slightly from the 2021 to 2050 timeframe.

BAU Methodology

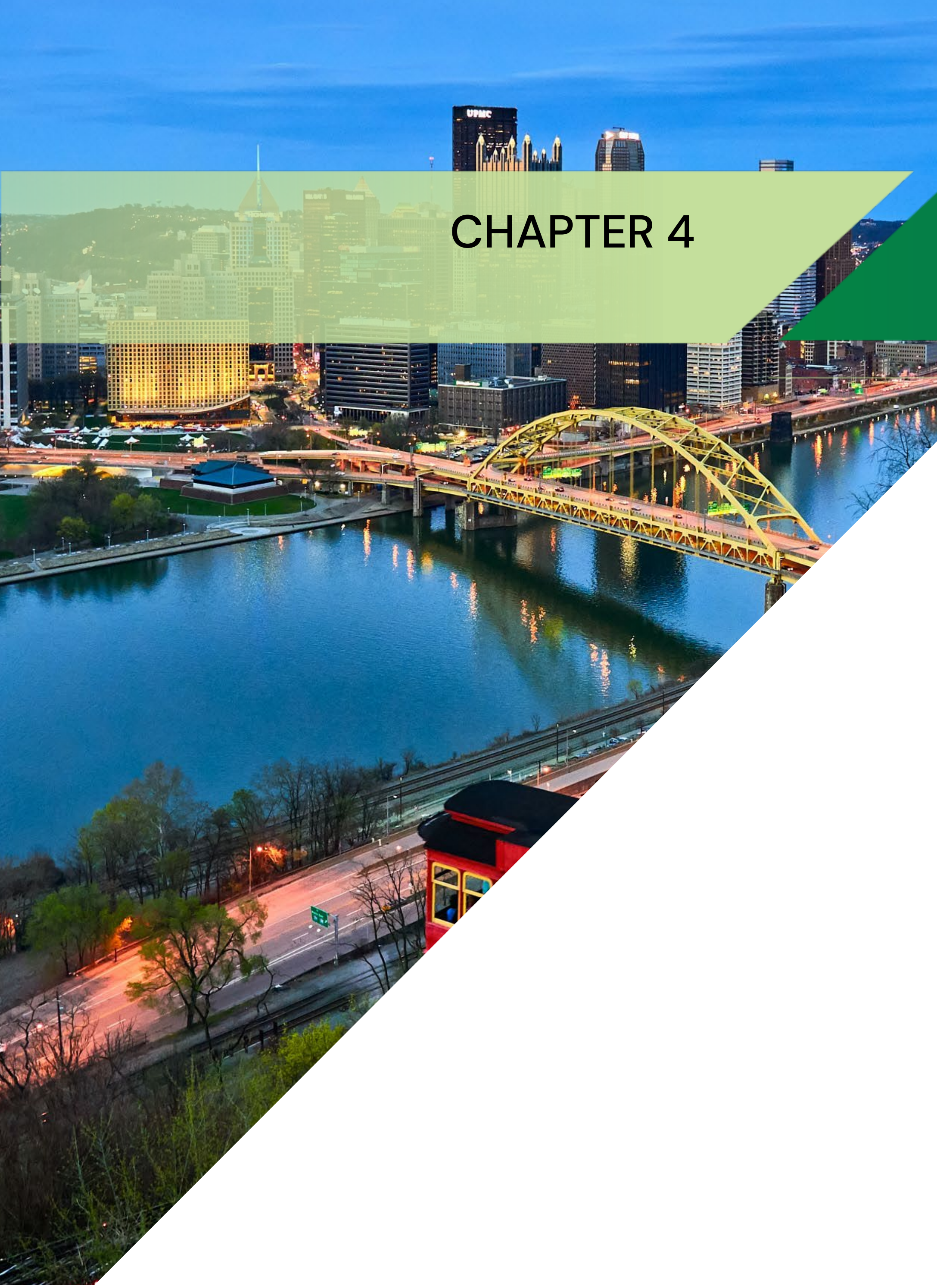
The BAU scenarios were modeled using the following data sources:

- **EPA's State Inventory Tool (SIT)**: The SIT is used for non-energy projections, including agriculture and waste. SIT provides a combination of population-based forecasts with other state-specific data.
- **State Energy Data System (SEDS):** Datasets from SEDS 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 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,
    - AEPS compliance reports,
    - Distributed solar data,
    - Oil and gas production and systems information,

- Biofuel production data,
- Vehicle registration data, and
- US Department of Energy (DOE)'s CHP Installation Database that ICF maintains (on combined heat and power [CHP] systems, loads, and more).

In addition to these datasets, the Reference BAU scenarios rely on data from ICF's Integrated Planning Model (IPM) to model the electricity sector through 2050 based on policies passed after AEO 2022, which was the basis for the Baseline BAU electricity emission factors.

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



CHAPTER 4

Greenhouse Gas Reduction Opportunities

Summary of Strategies

The GHG reduction strategies prioritized in the 2024 CAP Update will put Pennsylvania on track to achieve its GHG reduction goals while also providing valuable co-benefits across the Commonwealth. DEP has prioritized 22 strategies to reduce GHG emissions, five of which are new relative to the 2021 CAP (Table 9). Strategies from previous plans have been updated to include recent innovations in technology and the latest information to improve efficacy. The strategies are categorized into eight key sectors:

- Built Environment,
- Transportation,
- Industrial,
- Fuel and Gas Systems,
- Power Generation,
- Waste,
- Land Use and Agriculture, and
- Cross Cutting Technology.

Together, these strategies provide a cohesive, cross-sectoral pathway toward meaningful GHG reductions, improved health outcomes, economic growth, and a more equitable society.

Table 9. Summary of Emissions Reductions Strategies by Sector

Sector	Strategy Name	GHG Emissions Reduction[6] (2050)
Built Environment	**B1. Building Codes**: Improve energy efficiency of new buildings and major retrofits through codes.	**0.43 $MMTCO_2e$**
Built Environment	**B2. Electricity Efficiency in Buildings**: Deploy electricity efficiency in existing buildings.	**Included in P1.**
Built Environment	**B3. Gas Efficiency in Buildings**: Deploy gas efficiency in existing buildings.	**1.07 $MMTCO_2e$**
Built Environment	**B4. Building Electrification**: Deploy gas and fuel oil alternatives in existing buildings.	**7.43 $MMTCO_2e$**
Built Environment	**B5. Onsite Solar**: Deploy onsite solar, distributed energy resources and battery systems in buildings.	**Included in P1.**
Transportation Systems	**T1. TRANSIT AND MULTIMODAL IMPROVEMENTS**: **Expand transit, transit-oriented design, and multimodal transportation**. ***New***	**1.88 $MMTCO_2e$**
Transportation Systems	**T2. Light-Duty Vehicle Electrification**: Deploy EV and associated infrastructure.	**13.86 $MMTCO_2e$**
Transportation Systems	**T3. Zero Carbon Medium- and Heavy-duty Vehicles**: Implement low-carbon fuels and deploy zero carbon medium- and heavy-duty vehicles and associated infrastructure.	**11.49 $MMTCO_2e$**
Industrial	**I1. Industrial Efficiency**: Deploy electricity and gas efficiency in the industrial operations.	**7.10 $MMTCO_2e$**

[6] Annual reductions in GHG emissions compared to BAU Reference.

Sector	Strategy Name	GHG Emissions Reduction (2050)
Industrial	**I2. Gas, Fuel, and Process Decarbonization**: Electrify industrial uses, change processes, and deploy gas and fuel oil alternatives in industrial operations.	**8.39 $MMTCO_2e$**
Fuel & Gas Systems	**F1. Operational Efficiency**: Reduce methane emissions across oil and gas operations.	**7.25 $MMTCO_2e$**
Fuel & Gas Systems	**F2. Biomethane:** Expand use and generation of biomethane fuels.	**9.49 $MMTCO_2e$**
Fuel & Gas Systems	**F3. INACTIVE AND MARGINAL WELLS: Reduce methane emissions from inactive and marginal conventional oil and gas wells**. ***New***	**4.48 $MMTCO_2e$**
Power	**P1. Net Zero Grid**: Build a net zero carbon electricity grid.	**39.42 $MMTCO_2e$**
Power	**P2. DISTRIBUTION AND TRANSMISSION GRIDS**: **Ensure that electricity grid is ready for electrification related to peak load impacts and reliability**. ***New***	**Included in P1.**
Waste	**W1. Sustainable Organic Waste Management:** Divert organic waste from landfills and incinerators.	***Not Quantified***
Waste	**W2. Sustainable Construction Waste Management:** Support construction material salvage and reuse along with adaptive reuse of buildings.	***Not Quantified***
Land Use & Agriculture	**L1. Agriculture Best Practices:** Implement agriculture best practices for emissions reduction.	**0.02 MMTCO2e**
Land Use & Agriculture	**L2. Agriculture Best Practices:** Implement agriculture best practices for carbon sequestration.	**2.78 MMT CO_2e**
Land Use & Agriculture	**L3. Land and Forest Management:** Increase natural sequestration in Pennsylvania's land and forests.	**1.16 MMTCO2e**
Cross Cutting Technology	**C1. HYDROGEN FUELS: Expand use and generation of hydrogen fuels. *New***	**9.41 $MMTCO_2e$**

Cross Cutting Technology	**C2. CARBON CAPTURE, UTILIZATION, AND STORAGE: Deploy and continue to pursue new carbon capture technologies for power and industrial systems. *New***	**2.80 $MMTCO_2e$**

Pennsylvania's Pathway to 2050

Key Insights

Pennsylvania will make significant progress toward the US Climate Alliance's goal of achieving net zero emissions by 2050 if all the recommended decarbonization strategies above are effectively implemented. Figure 13 demonstrates a pathway to achieve a net reduction of 238 $MMTCO_2e$ (an 80% reduction) from 2005 levels by 2050, with a total reduction of 176 $MMTCO_2e$ beyond the Baseline BAU level. The reductions from the strategies in this CAP approach the 50% reduction goal by 2030.

The Electricity generation, fuel supply, and transportation sectors have the largest potential for emissions reductions in the state over time. A breakdown of emissions reductions by sector is provided in Figure 14.

Table 10. Modeled GHG Reduction Results Compared to Set Goals

Year	Goal	Results
2030	50% reduction	40%
2050	Net zero emissions	80%

Figure 13. Comparison of Strategy Results to Baseline Scenarios and Goal

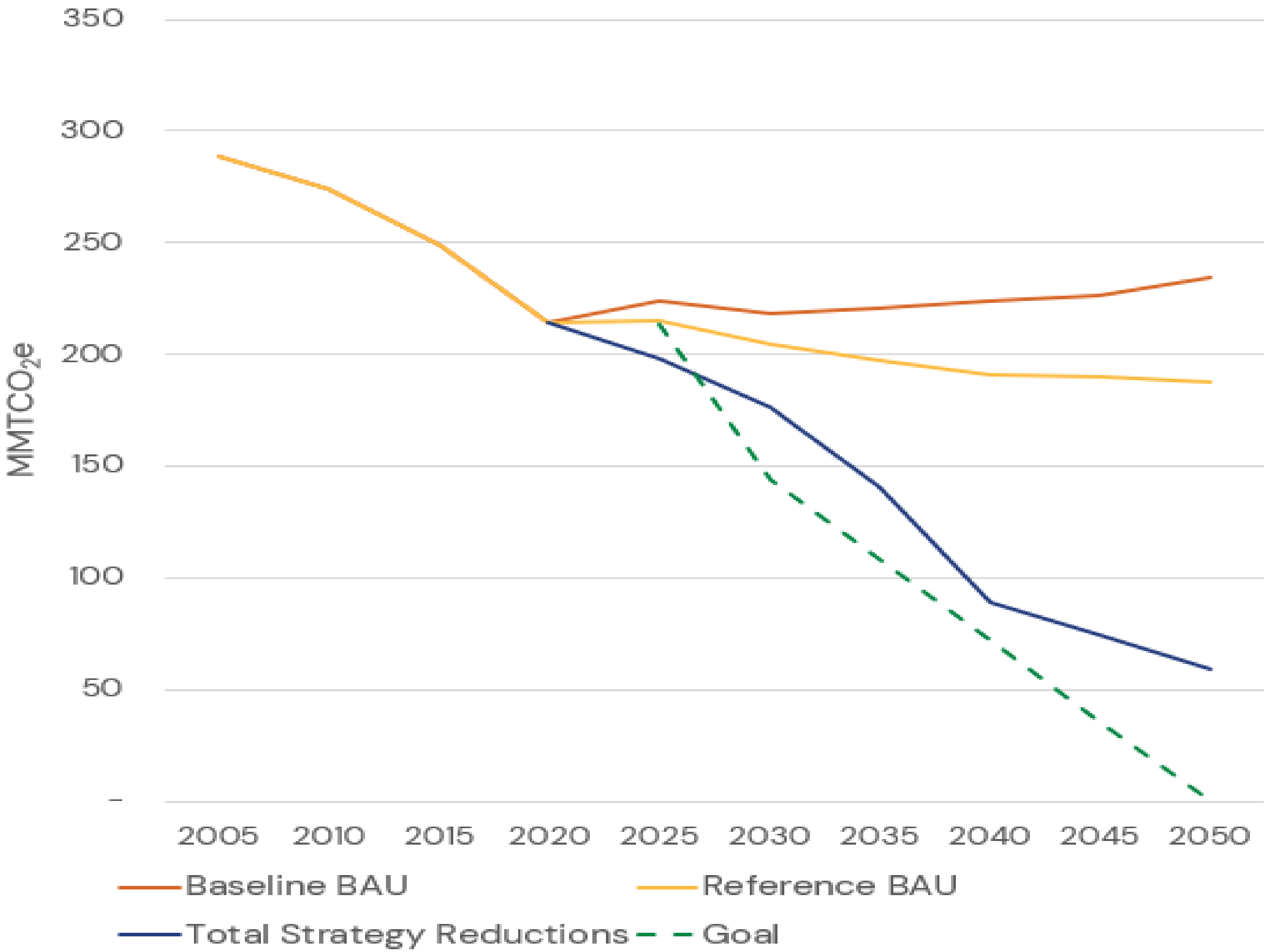
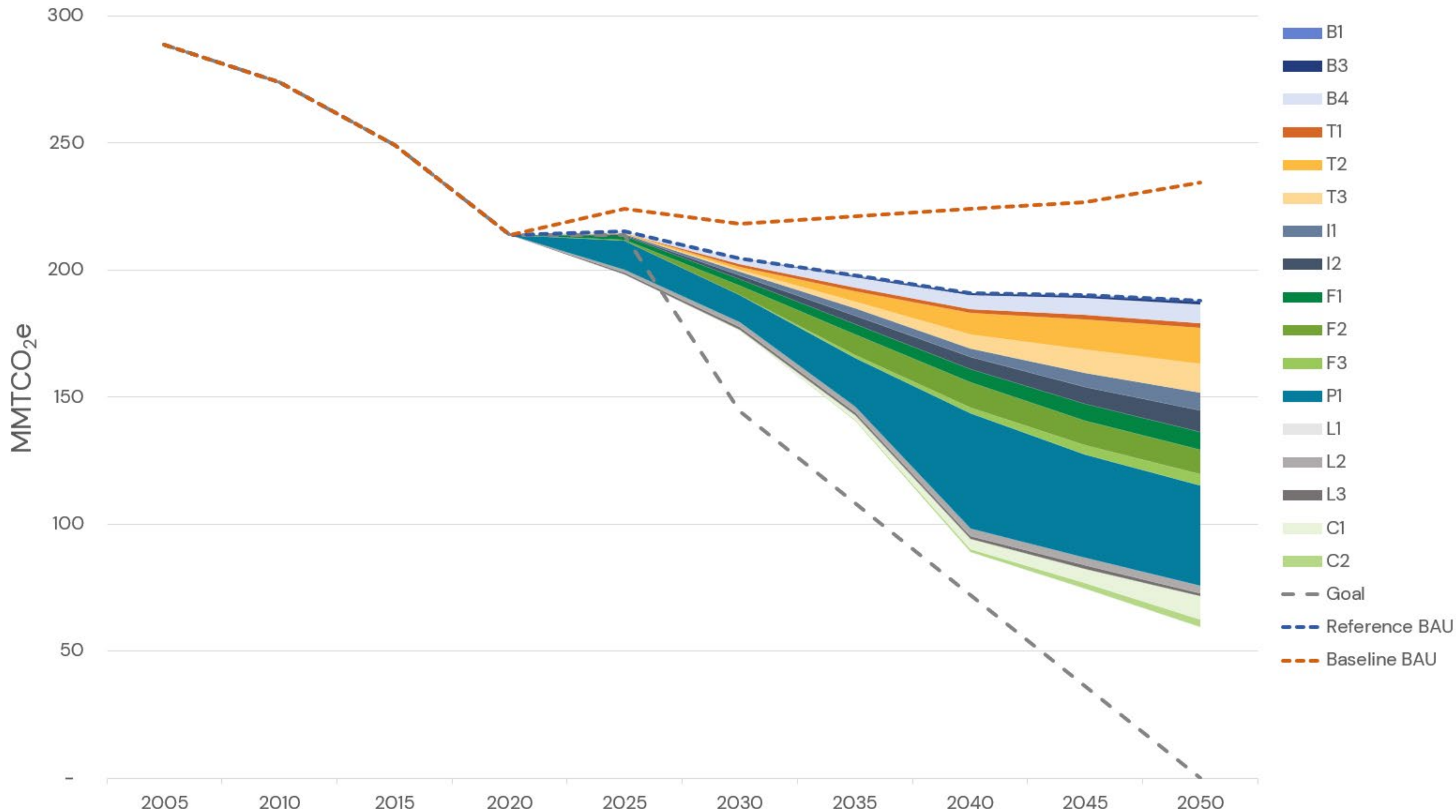
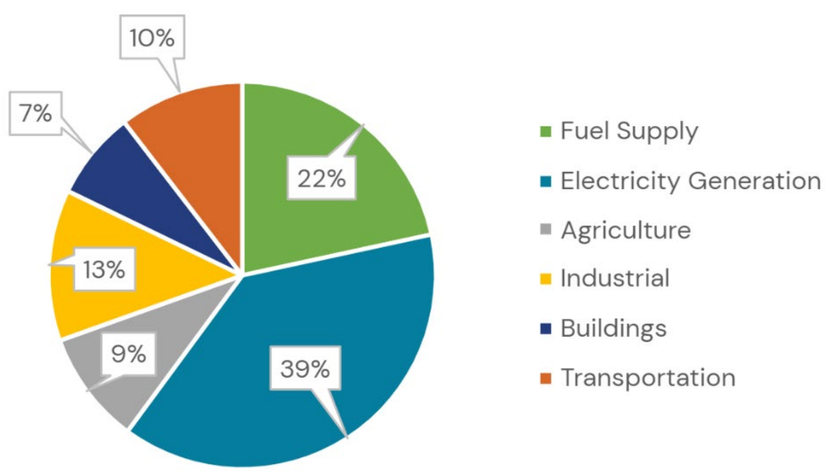


Figure 14. Sector Share of Total GHG Reductions Achieved Through Strategy Implementation in 2050 ($MMTCO_2e$)



By implementing all modeled strategies, Pennsylvania could reduce GHG emissions in 2030 by more than 40% below 2005 levels. By 2025, strategies to reduce emissions from fuel sources will play the largest role in reducing overall emissions to reach this target at a projected reduction of 11.8 $MMTCO_2e$. Pennsylvania's transition to cleaner fuel sources like renewable natural gas and hydrogen will contribute to these critical emissions reductions while also providing reliable fuel sources for the state. Additionally, the agriculture and transportation sectors will each account for approximately a quarter of the state's 2025 emissions reductions. Transitions to cleaner and more sustainable agricultural practices and low-to-zero emissions vehicles are already underway in the state and the strategies put forward in this plan lay a pathway forward to make this transition work for the state's economic needs while also providing protections for Pennsylvania forests and natural lands. See Figure 15 for a distribution of reductions by sector in 2030.

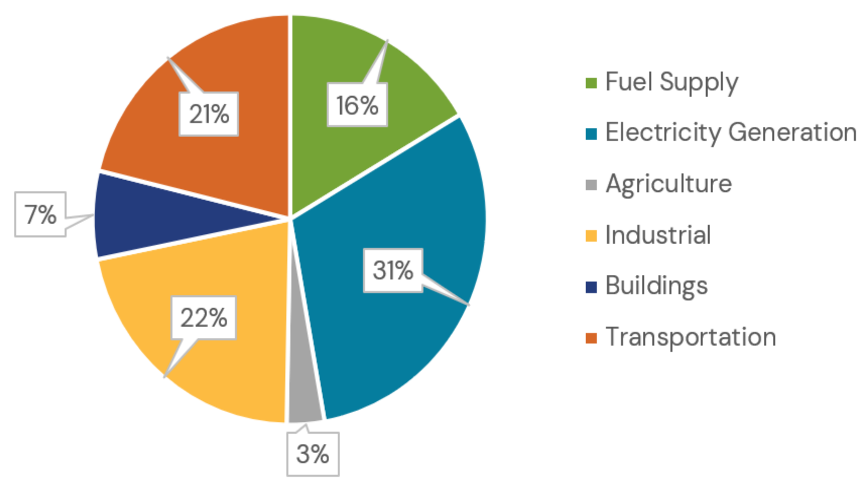
Figure 15. Sector Share of Total GHG Reductions in 2030 Achieved Through Strategy Implementation ($MMTCO_2e$)



By 2030, the current strategies pathway results in a net emissions reduction of 40%. This does not achieve the US Climate Alliance goal of a 50% reduction by 2030 and accelerating action to align with this target would be advised for strategies across all sectors.

Pennsylvania will near the path to net zero by 2050, reducing GHG emissions by nearly 80% from 2005 levels with the implementation of all modeled strategies in all sectors. Strategies to reduce GHG emissions from electricity generation offer the greatest potential for decarbonization through 2050, followed by emissions from industrial sources, transportation, and buildings. Nuclear, solar, onshore wind, and battery storage will need to produce nearly all the electricity generated in Pennsylvania by 2050. See the distribution of reductions by sector in Figure 16.

Figure 16. Sector Share of Total GHG Reductions in 2050 Achieved Through Strategy Implementation ($MMTCO_2e$)



More reductions will be needed to meet both short (2030) and long (2050) climate goals; however, Pennsylvania will near the path to net zero by 2050. Strategies support strong decarbonization, particularly in the power generation and transportation sectors. To reach and exceed stated goals, the Commonwealth will need additional decarbonization strategies with a particular focus on harder to decarbonize sectors such as industry, fuel and gas, and buildings. Additionally, developing and intentionally planning decarbonization, using approaches that work across and between sectors will be critical. This plan includes a handful of cross cutting strategies based on new and emerging technologies such as hydrogen and carbon capture, which could see more robust deployment. Other technologies, as well as deeper and more aggressive deployment will also need to be pursued.

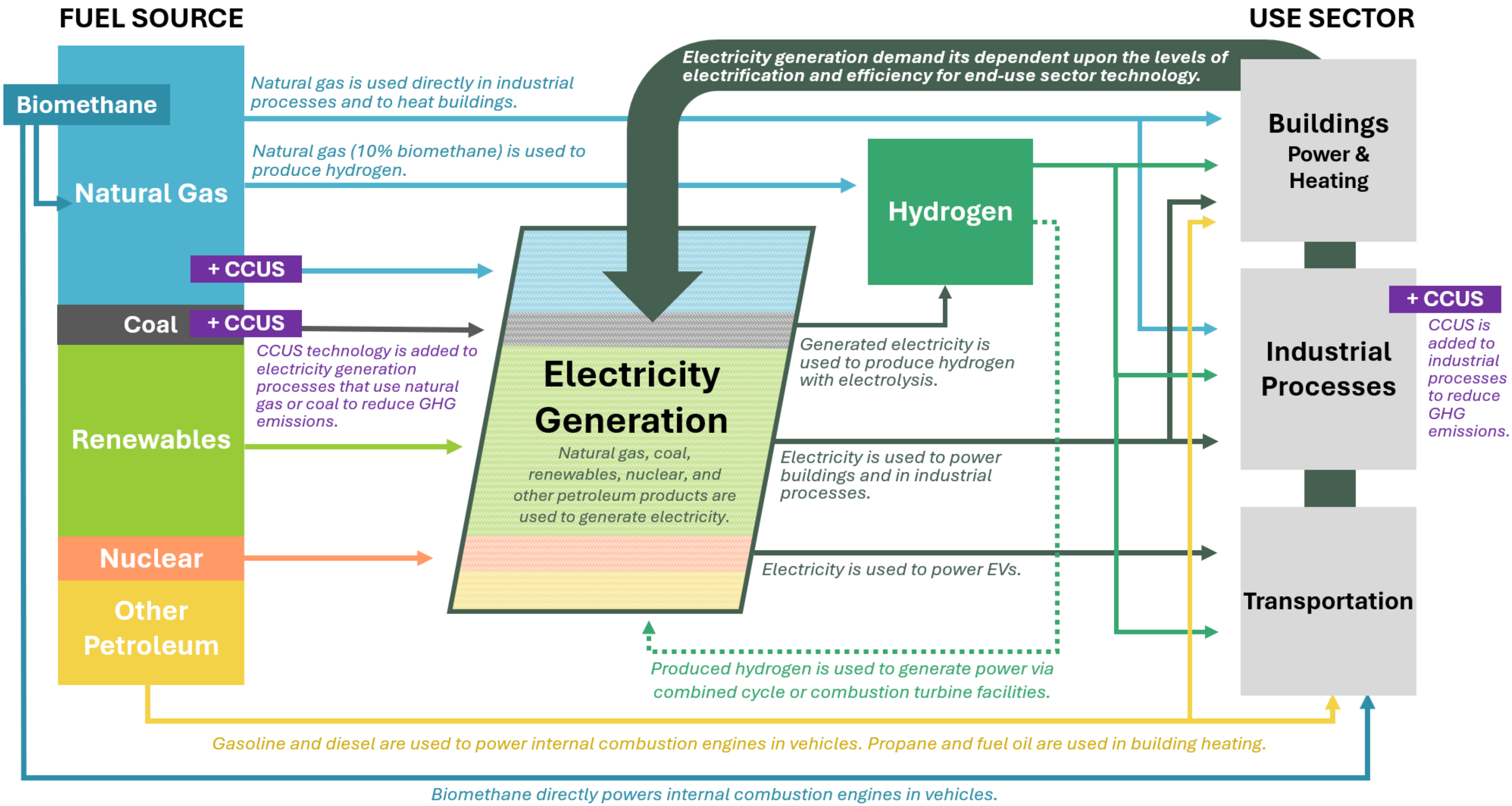
A clean grid is central to decarbonization of nearly every sector including buildings, transportation, and industry. Decarbonization of the electricity grid is foundational to the success of Pennsylvania meeting its climate mitigation goals since electricity already touches all major sectors. A low-carbon grid will support emission reductions from building, transportation, and industrial electrification, as well as the production of low-carbon hydrogen from electrolysis. By shifting toward renewable energy and battery storage, nuclear, carbon capture technologies, and the use of low-carbon fuels, reductions from electricity generation have the potential to touch many sectors (see Figure 17).

Clean Fuels in Both Power and End-Use Sectors

Since the release of the previous CAP, additional focus and research has been conducted regarding clean and low-carbon fuels such as biomethane and clean hydrogen. Numerous strategies in this CAP make use of or support clean fuels which will likely play a prominent role in Pennsylvania's low-carbon pathway to 2050.

Clean fuels have complex relationships with energy flows, as they can be used to either produce electricity or for direct consumption in end-use sectors. Figure 17 illustrates these energy flow relationships and shows the myriad of pathways that may be considered for decarbonizing the fuel and electric power sectors. Clean fuels development should focus on the best use cases – i.e., hard-to-electrify processes or where it offers a more reliable, low-cost solution – while also considering how clean fuel production may lead to tradeoffs. For example, some clean fuels are developed using electricity (e.g., green hydrogen), which requires building dedicated renewable energy sources to create hydrogen rather than direct electricity supply for the grid. Between now and 2050, electricity demand across the Commonwealth will vary based on the pace of electrification and efficiency improvements across end-use sectors. Rightsizing clean fuels development and understanding where it can best be utilized will be key considerations when implementing CAP strategies across sectors.

Figure 17– Relationships between fuel sources, electricity generations, and end use sectors



Approach

The 2024 CAP provides updated and new analysis, incorporating legislative and technological changes since 2021. For the 2024 CAP, the ICF team worked with DEP and CCAC in an iterative process to develop a comprehensive list of potential GHG reduction strategies based on existing Pennsylvania climate and energy resources and ICF expertise. This work started with the 2021 CAP GHG reduction strategies, and the analysis team then worked with DEP and the CCAC to identify which strategies to model and evaluate. In developing strategies, a range of DEP priorities were considered including: GHG reduction magnitude and cost effectiveness, EJ and equitable implementation opportunity benefits, and air quality and public health benefits.

Process to Identify Potential Strategies

The 2021 CAP was reviewed to gather initial strategy ideas. Key policy and technology updates since the previous CAP were then reviewed, and strategies were updated as needed to respond to observed trends. Additional strategies were also added to respond to the changing needs of the state based on legislative, economic, and technology changes affecting Pennsylvania.

The following criteria were used to evaluate potential strategies for the Commonwealth to act on. Criteria included:

- **GHG Reduction Potential:** Considers the maximum amount of GHG reduction possible as a result of strategy implementations and how the timing of those potential reductions could help Pennsylvania achieve, or exceed, its climate targets.
- **Costs**: Considers the cost effectiveness of implementing a strategy based on the overall cost (or savings) per ton $MTCO_2e$/reduced.
- **Jobs**: Considers the jobs created to have a successful implementation and maintenance of a strategy and the economic benefits of that workforce development.
- **Co-Benefits**: Considers benefits other than GHG reduction and jobs which are valued by Pennsylvania and contribute to other state goals and overall values.
    - **Environmental:** Considers improvements to both urban and rural ecosystems in Pennsylvania, for example, preservation of biodiversity, improved soil quality, or decreased urban canopy coverage.
    - **Economic:** Considers positive impacts on productivity, community investments, property value, savings on public service costs.
    - **Social and Health:** Considers outcomes for social equity and public health based on improved environmental conditions and economic opportunities.

Embodied Carbon Versus Energy Use Tradeoffs

Embodied emissions or embodied carbon is a term to reflect the GHG emissions associated with creating materials and undertaking construction. The term captures the emissions released in the life cycle of a material or infrastructure asset to extract raw materials from their sources, transport them to factories, manufacture building materials and products, transport them to the construction site, construct and maintain the building, and potentially demolish it after a certain service life span. While the term often incorporates a “full life cycle” or “cradle-to-grave” connotation, it can also refer to partial life cycle. For example, the “cradle-to-gate” embodied carbon, also known as upfront carbon, captures the GHG emissions of the building material production before materials are shipped to the construction site.

Though embodied carbon was not modeled in this CAP due to limitations, a growing number of national, state, and local governments are placing increasing attention on policies, building codes, and programs to decrease the embodied carbon. There are additional efforts to explore ways to reduce emissions throughout the lifecycle of—not only building materials—but also of products and technologies used in other sectors like transportation. During strategy implementation, opportunities to reduce embodied carbon should be explored and some of these are highlighted in this CAP. For more information on embodied carbon please see Embodied Carbon.

GHG Reduction Accounting Approach (Building On BAU), with Specifics for Power Sector

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 and methods similar to what were used to conduct the 2021 CAP analysis with a handful of new tools and approaches developed as part of ICF’s CO_2Sight decarbonization platform. The integration of various sector level modeling work was primarily conducted using Excel. ICF also made 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. Key aspects of the 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).
- Reductions in GHG emissions as a result of changes in both electricity consumption and the generation mix are accounted for in the electricity generation sector. 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 it (e.g., energy efficiency, electrification).
  - Feed the load changes over time into IPM© with policy assumptions to project generation mixes over time.

  Reductions in GHG emissions as a result of changes in end-use electricity consumption are not included in sector totals to avoid overlapping GHG reductions from different sectors and actions (i.e., “double-counting”).
- Layering the impacts of certain strategies to avoid overestimating 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).

Please refer to APPENDIX B Methodology for more details on the GHG Reduction Accounting Approach.

Economic Modeling

Approach

The analysis team used the REMI PI+ model to estimate the macroeconomic impacts of the various GHG reduction strategies for the Commonwealth residents.[7] The REMI model integrates several analytic techniques and can be used to estimate the national, regional, and state-level impacts of policy changes.

The team used inputs such as capital costs, operation and maintenance costs, and fuel and energy costs for the various sectors (building, transportation, industrial, fuel supply, power, agriculture, and cross cutting technologies) in REMI to model the CAP strategies and estimate the macroeconomic impacts. REMI links 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 remain.

The economic impacts modeled in REMI do not consider potential co-benefits and costs such as improvements to environmental quality or public health, nor do they consider equity or EJ.

All dollars presented in the plan are representative of 2024 dollars. For further details on the economic modeling methodology, please refer to APPENDIX B Methodology.

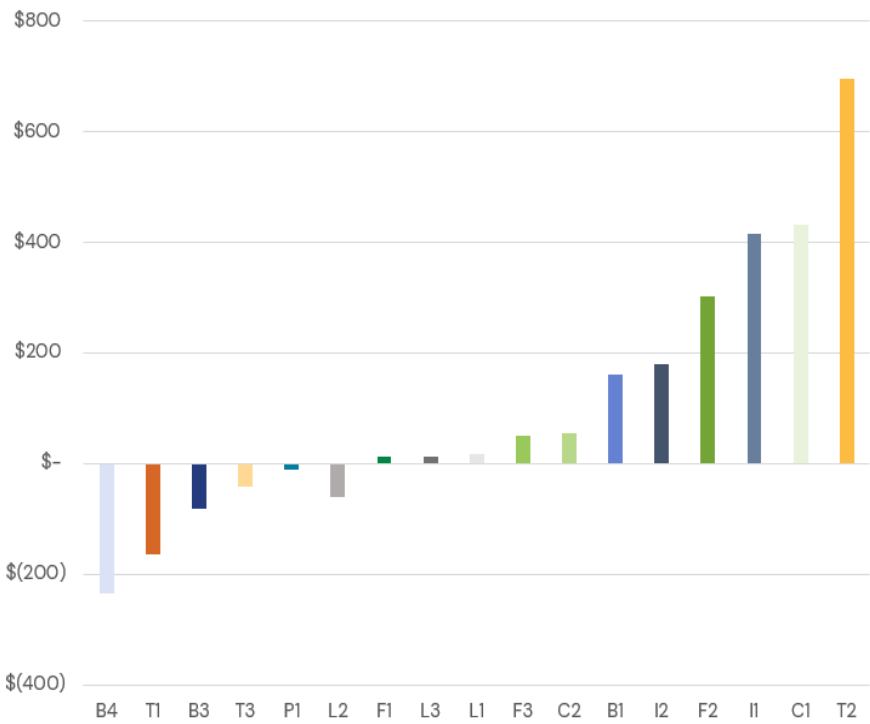
Marginal Abatement Cost Curve

The marginal abatement cost (MAC) curve shows the cost or savings associated from different strategies that reduce GHG emissions along with the amount of emissions that the strategy will reduce if implemented. The MAC curve compares the financial cost and the reduction potential of GHG reduced for each strategy, essentially providing the cost of one metric ton of carbon reduced.

[7] REMI is a 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, including in prior versions of this CAP and in other 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.

Figure 19 shows the cost to reduce one metric ton of carbon for each of the strategies modeled. It can be seen that a few GHG reduction strategies result in overall cost savings, as seen in improving electricity and gas efficiency in residential and commercial buildings and reducing overall vehicle miles traveled, where the MAC is negative. Alternatively, electrifying light-duty vehicles and implementation of green hydrogen would experience a higher cost to reduce the same unit of carbon emissions.

Figure 18. Marginal Abatement Cost Curve by GHG Reduction Strategy



Results

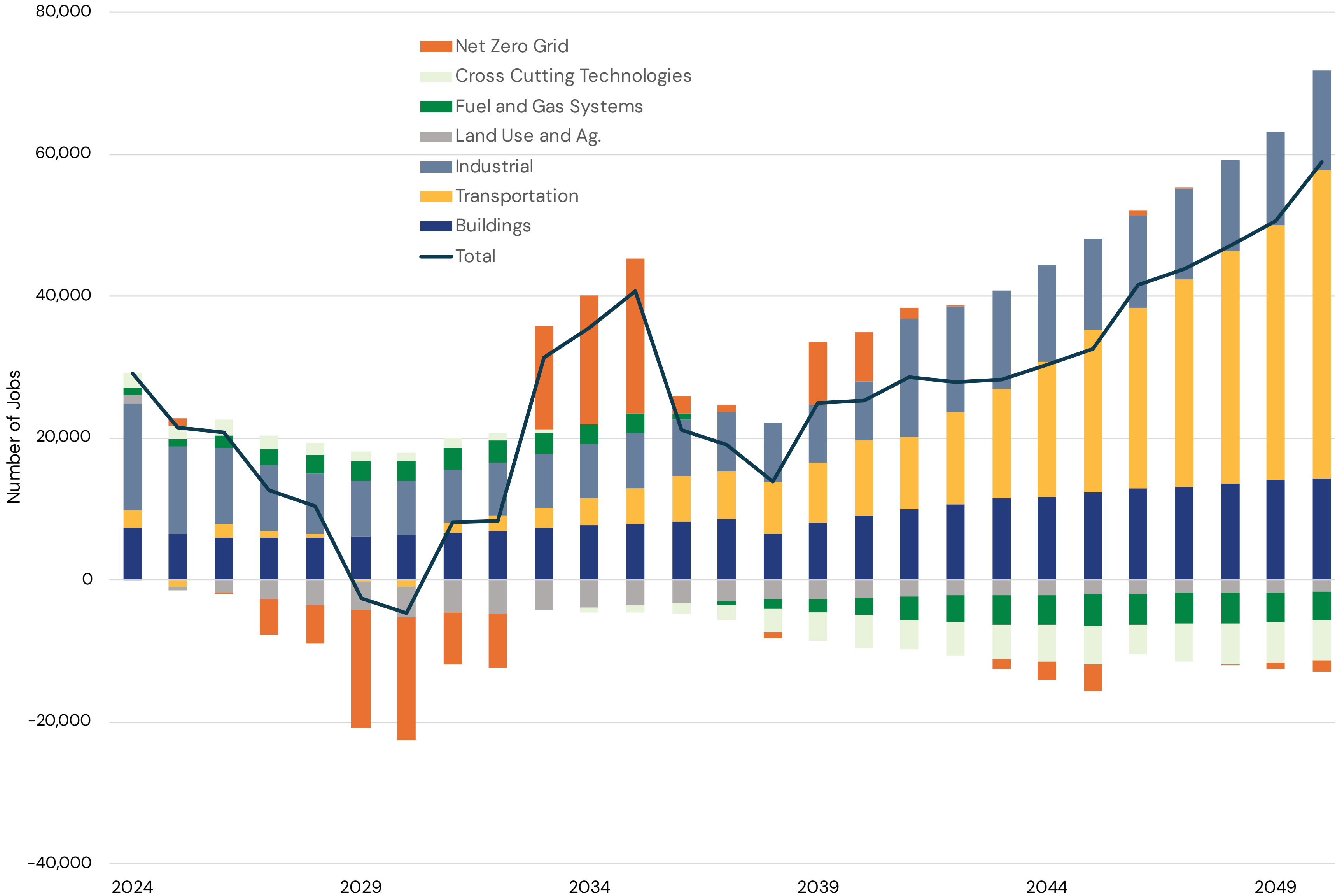
This section describes the results from economic modeling using REMI PI+ as described in the economic modeling approach section. Strategies affecting buildings, transportation and the industrial sectors have positive economic impacts. Certain strategies, such as those with cross cutting implications (consisting of hydrogen fuel and CCUS) appear to result in some job losses, but notably many of these strategies have other benefits captured in other strategies, as discussed in the strategy details below.

Strategies affecting the fuel and agriculture sectors also lead to small decreases in economic activity or jobs. The net zero grid strategy initially has decreases in jobs due to a shift away from conventional natural gas. Beginning in 2033, a large amount of battery storage, solar, and natural gas with carbon capture and storage (CCS) results in a period of increased jobs associated with construction and operation. In subsequent years the positive

(renewable and CCS jobs) and negative (conventional natural gas and ratepayer impacts) jobs offset each other so that net job increases and decreases under the net zero grid strategy between 2036 and 2050 tend to be small. For most years, the strategies that lead to positive economic impacts more than offset those that lead to negative impacts, such that for most years, there is a net

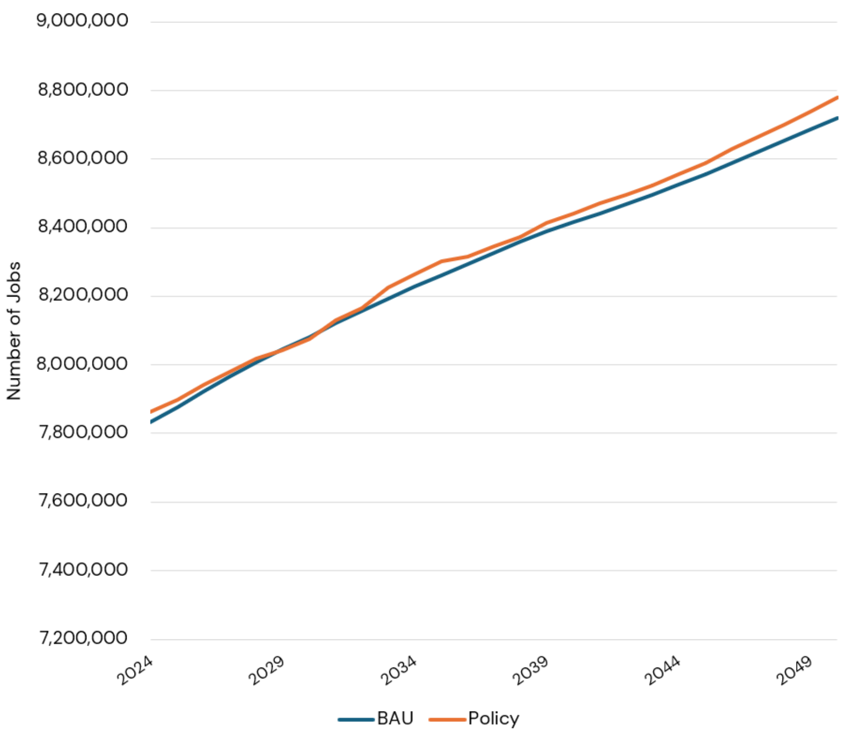
positive impact on jobs in the Commonwealth. The annual net job increases vary by year (e.g., in 2050, the total number of jobs supported by these strategies is about 58,000), with an annual average increase of about 26,000 jobs. Combined, the strategies

Figure 19. Summary Employment Under the Strategies



are estimated to result in an increase of approximately 700,000 cumulative job-years by 2050.[8] To put these results in context, the macroeconomic impacts estimated here are relatively small compared to the size of Pennsylvania's economy. The average annual employment impact is estimated to increase by about 0.31% compared to the BAU for the entire modeling period.

Figure 20. Employment Levels under the BAU and Combined Strategies



[8] 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.

Figure 19 and Figure 20 summarize the cumulative employment impacts of all the strategies analyzed for this study. Figure 19 shows the job impacts by different strategy groups, such as those affecting buildings, transportation, etc., along with the net job impact shown as the "Total" line. Figure 20 shows the cumulative impact of these strategies in relation to the trends under the BAU. Note that the "Policy" line in Figure 20depicts the aggregate impacts under all the strategies combined, similar to the "Total" line in Figure 19 above.

The overall impact on GSP is a slight increase from the BAU baseline with an annual average increase of about 0.02%. Although visually indistinguishable, the GSP BAU and policy scenarios are shown in Figure 21 where the Policy line shows the aggregate GSP impacts of all strategies combined. Figure 21 shows that although the incremental aggregate impact of the strategies combined are indistinguishable, the Commonwealth economy continues to grow at a robust pace, both under the BAU and with the implementation of the CAP.

Modeling suggests there is the likelihood of a slight decrease in DPI compared to the BAU levels, with an average annual decrease of 0.26%. This slight decrease in disposable income is likely driven by the cumulative impacts of energy rates from all the strategies combined and the possibility of Commonwealth residents paying slightly more for their energy needs, relative to the BAU. DPI levels for Commonwealth residents continue to grow robustly under effect of these strategies combined (i.e., the Policy line in Figure 22).

Figure 21. GSP Levels Under the BAU and Combined Strategies

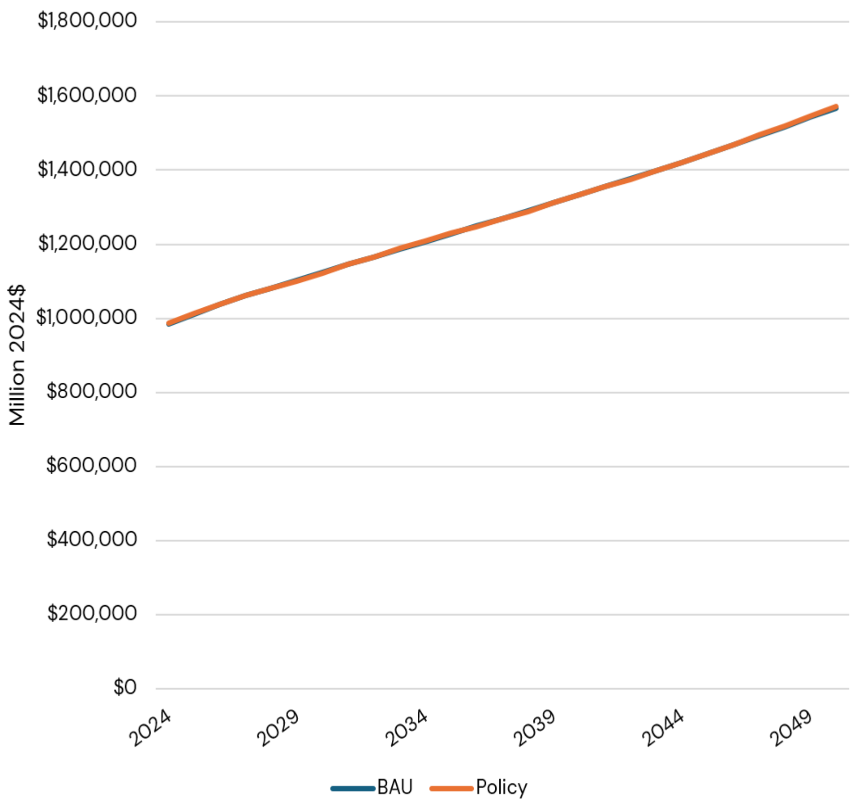
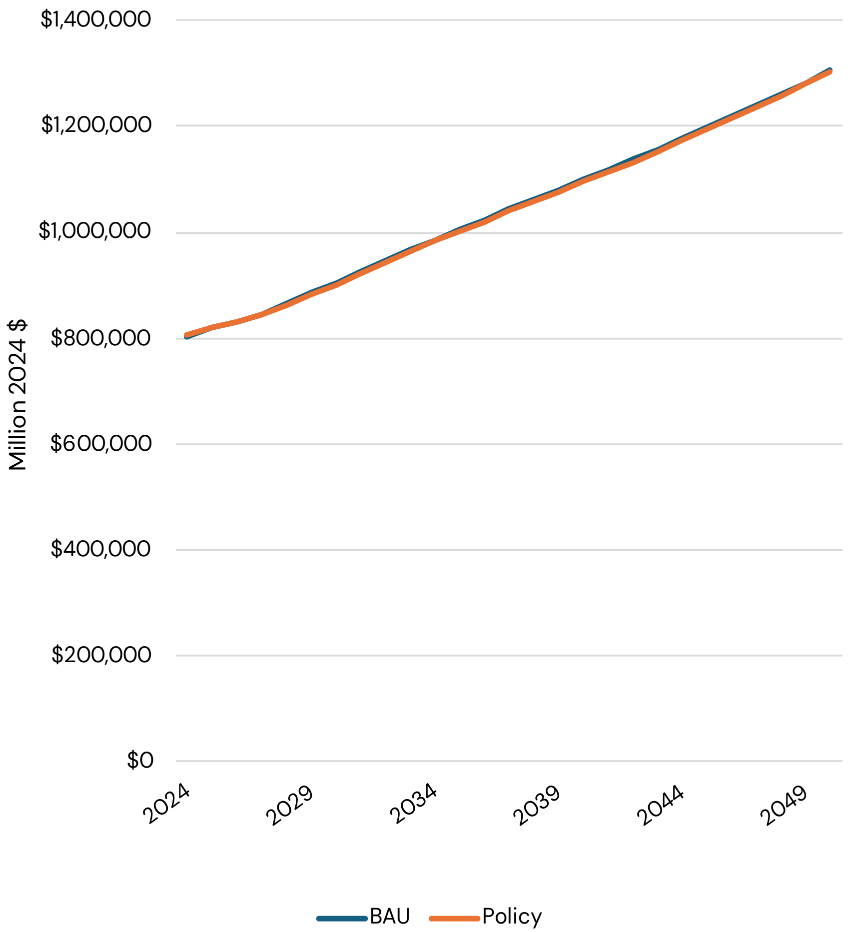


Figure 22. DPI Levels Under the BAU and Combined Strategies



As Figure 22 shows, the rates of growth in disposable income under the BAU and the Policy line are virtually indistinguishable with income levels rising at rates very similar to the BAU baseline.

Built Environment Sector

The diversity in building types, vintages, and sizes of Pennsylvania's building stock presents a unique set of challenges for energy efficiency and GHG reductions through the built environment. This sector primarily focuses on residential and commercial buildings, including homes, apartment complexes, businesses, institutional facilities (e.g., schools, hospitals), and other large buildings. These buildings typically consume fuel on site, primarily for space- and water-heating needs and use electricity to generate heating and cooling in spaces, power lighting and electronics, heat water, and cook food. Emissions reductions from electricity use are not included in the built environment sector; they are included in the electricity generation sector; however, electricity efficiency is described in this section.

Residential

There are millions of residential buildings in Pennsylvania including single-family homes, multifamily homes as well as manufactured housing. Pennsylvania's building homes, like its buildings stock tend to be old and are less efficient than a home built to current energy codes. More than half of Pennsylvania households use natural gas as the primary fuel home to heat their homes.[9]

Emissions from the residential sector have decreased 25% since 2005 while emissions from the commercial sector have decreased by 17% over the same period. Such reductions can be attributed to the transition to lower-emitting fuels, energy efficiency improvements that reduce the need for fuel consumption, and technological improvements. However, EJ and low-wealth areas have not had equitable access to these improvements due to a combination of factors including, but not limited to, high upfront costs, workforce gaps for Weatherization Assitance Programs, and additional challenges for renters and multifamily homes.

Commercial

Pennsylvania's commercial buildings (office buildings, restaurants, grocery stores, retail shops, lodging, schools, hospitals, and warehouses) use energy in a range of different ways. Within Pennsylvania there are approximately 190,000 commercial natural gas[10] customers using onsite gas.

Since 2005, emissions from the commercial sector have decreased by about 17%, with the transition to lower-emitting fuels, energy efficiency improvements, and technological improvements all playing a crucial role in reductions, much as they did in the residential sector.

Strategies

For both residential and commercial buildings, strategies to improve building codes and energy efficiency, as well as increased electrification of heating, can help to reduce fuel burning and associated emissions. Additionally, targeted outreach, relevant education, and incentives for low-wealth and minoritized communities can help increase the adoption of emissions

[9] "State Energy Profile Data." US EIA. https://www.eia.gov/state/data.php?sid=PA

[10] "Pennsylvania Natural Gas Outlook Report." Pennsylvania PUC. 2022. https://www.puc.pa.gov/media/2180/gas_outlook_report2022.pdf

reductions technologies and associated co-benefits (including improved air quality and utility bill savings) in these communities.

The strategies proposed to address building emissions reflect existing technological and policy trends that aim to improve energy efficiency, incentivize electrification, and add clean onsite energy production. Five strategies are modeled for this sector, and together, the modeling results indicate that these strategies will reduce emissions compared to the Reference BAU in 2030 by 2.1 $MMTCO_2e$. In 2050, these strategies will reduce emissions in the buildings sector by 8.94 $MMTCO_2e$. Table 6 shows the identified strategies and the modeled emissions reductions from each in 2030 and 2050.

Benefits Quantification

Note that for P1, P2, B2, and B5, GHG reductions were modeled and reported collectively. This modeling indicates how the full potential GHG reduction achieved by each strategy is co-dependent on the successful implementation of all of these strategies. Additionally, for P1, P2, B2, B4, and B5, the cost (or benefit) per ton $MTCO_2e$/reduced were modeled and reported collectively because these strategies have significant overlap of their implementation costs and benefits.

For each strategy, the environmental 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 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.

Table 11. Building Sector GHG Reductions Strategies and Associated Reductions ($MMTCO_2e$)

GHG Reduction Strategy	2030	2050
B1. Building codes[a]	0.02	0.43
B2. Electricity efficiency in buildings[b]	N/A	N/A
B3. Gas energy efficiency in buildings[a]	0.11	1.07
B4. Building electrification[a]	1.96	7.43
B5. Onsite solar[b]	N/A	N/A

N/A = Not Applicable.
[a] A portion of GHG reductions from this strategy is captured in the electricity generation sector.
[b] The GHG reductions from this strategy are captured in the electricity generation sector.

Equity in the Built Environment Sector

Accessibility: Accessing the benefits of this sector will primarily rely on affordability, technology literacy, clear program requirements, infrastructural readiness for upgrades, and buy-in from property owners to support the needs of renters and others lacking decision-making autonomy. This will require sufficient funding of programs to address building efficiency, weatherization, and other services to low-wealth communities as well as Pennsylvanians not living in single-family homes, like apartment renters or those living in multifamily homes. Additionally, funding efforts should aim to address potential ratepayer inequities that may arise from the implementation of these strategies, especially since non-adopters in opt-in programs are more likely to be low-wealth customers.

Advocacy: Strategy implementation in the built environment sector should particularly account for the impacts on those experiencing high energy burden, income stress, tenants, and individuals with health vulnerabilities.

Accountability: Accountability should be mechanized in this effort through a dynamic process that allows for engagement, flexibility, and transparency.

B1. Building Codes

Develop improved building codes for new buildings and major retrofits to improve energy efficiency.

This strategy includes promoting use of the most current building codes, specifically a single stretch code to encourage low-carbon facilities and allow uniform adoption across the Commonwealth. This strategy also includes working to ensure that code officials and inspectors are trained and empowered to enforce the code. Stretch codes are alternate building codes or compliance pathways that result in higher energy savings by including more aggressive requirements than the base code.[11] A stretch code could align with existing "stretch codes" such as International Green Construction Code (IgCC), Zero Code, NetZero Codes.

Green infrastructure and nature-based solutions could also be explored and further added to building codes to reduce heating and cooling needs through reductions in paved surfaces and to increase resiliency.

KEY METRICS

GHG emissions reductions:

2030: **0.02 $MMTCO_2e$**
2050: **0.43 $MTCO_2e$**

Cost (or benefit) per ton $MTCO_2e$/ reduced: **$162/$MTCO_2e$**

Resulting Impacts

Environmental

Current building codes, along with stretch codes that could be promoted by the Commonwealth, can reduce the amount of electricity and gas that is consumed by buildings. This reduction will reduce the emissions of CO_2 and other GHGs associated with electricity generation and gas consumption (e.g., CH_4 and N_2O). Additional gaseous and particulate emissions associated with electricity generation and gas consumption would also be reduced, such as NO_x, SO_x, $PM_{2.5}$, and volatile organic compounds (VOCs) that are ground-level ozone precursors.

Economic

The adoption and enforcement of the model residential and commercial codes increases upfront costs of construction but provides overall savings when compared to existing codes. Annual savings for homes that are built to the latest code provides annual savings of $556 per household and $130 per commercial square foot,[12] and results in lifetime energy cost savings to those who renovate or build new buildings to the new building code.

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[11] "Illinois Stretch Code." Smart Energy Design Assistance Center (SEDAC), University of Illinois, Urbana-Champaign. January 13, 2022. https://smartenergy.illinois.edu/illinois-stretch-code/.

[12] "Pennsylvania: Building Energy Codes Program." US DOE. n.d. https://www.energycodes.gov/status/states/pennsylvania.

Social and Health

Current building codes, along with the adoption of stretch codes, reduce emissions associated with the generation of electricity and the consumption of gas. Impacts improve community air quality, increase comfort, and improve affordability, all of which lead to improved health and social outcomes.

Homes that are built to codes have improved energy efficiency, leading to reduced energy costs, and reducing energy burden for households experiencing the impact of increasing temperature in the Commonwealth. Building codes are also important in securing the resilience and safety of a structure, protecting it from the harms of climate induced hazards such as flooding, fire, storms, and landslides. These events are most likely to cause both short and long-term harm on low-wealth and EJ areas due to historic under-resourcing and exclusion from energy and housing benefits.

Additionally, ensuring code compliance is critical for low-income housing availability as buildings must be up to code to accept Section 8 housing vouchers. In this manner, code compliance can contribute to closing the housing-equity gap while providing climate and other economic benefits.

RELATED FUNDING OPPORTUNITIES

Technical Assistance for the Adoption of Building Energy Codes

A $1 billion provision of the IRA in adopting the latest national model building energy codes and pursuing zero energy codes. The first round of funding of $400 million is being allocated on a formula grant basis. Of this first funding Pennsylvania is expected to receive, approximately $8.7 million of which $5.2 million will be used to adopt latest codes and $3.5 million will be used for pursuing zero energy codes.

Implementation Considerations

There are a range of ways that improved building codes (including stretch codes) could be developed to support energy efficiency. The following actions could be taken as part of implementing this strategy:

- Maintaining updated buildings codes and creating, adopting, and promoting a single stretch code for the Commonwealth.
- Supporting local code officials and inspectors through training and educational resources.
- Simplifying the complex review process of the Review and Advisory Council (RAC). The current process of approving changes to the building codes through the RAC is challenging, as potential changes must go through an extensive review and adjustment process before they can be passed. Improvements like setting up autoenrollment for approvals or shifting the authority to adjust building codes to a local level could help simplify the review process. Additional details on legislative recommendations can be found in CHAPTER 7 Legislative Recommendations.

Partners and Participants

- **Pennsylvania legislators**: Any changes to the Commonwealth's process for adopting energy codes would need to be passed by Pennsylvania's legislators.
- **Builders, construction companies, and related trades**: Builders and regulators will be implementing changes to buildings in accordance with codes. Support is needed from trade groups to train builders and contractors on the latest updates to building codes.
- **Housing providers, landlords, and developers**: Parties who own and oversee properties across the state have the responsibility to ensure compliance with new and existing building codes while also managing how any upgrades might impact tenants.
- **Pennsylvania Housing Finance Agency (PHFA):** PHFA provides key financing services for new homebuyers, homeowners, and renters to provide loans that increase accessibility for affordable housing and help finance home upgrades like weatherization.
- **Inspectors and regulators**: Inspectors and regulators are key implementers of building codes, responsible for assessing compliance of new and existing building supply with standards of the code. Support for inspectors and regulators can include training for increased understanding of how to review buildings for compliance.
- **Local energy/climate nonprofits**: Energy nonprofits such as local chapters of the US Green Building Council can participate in marketing, outreach, and education with Pennsylvania residents can increase awareness of the benefits of new building codes and energy efficiency and conservation (EE&C) programs, as well as demand for programs run by electricity utilities.
- **Pennsylvania Housing Alliance, PA Developers Council, and other housing advocates**: Groups advocating for affordable and equitable housing protections in the Commonwealth provide resources to connect low-wealth Pennsylvanians with financing options (e.g., Low-Income Housing Tax Credit), consumer education, home upgrade opportunities (including code compliance upgrades), and more.

Financial Considerations

Depending on the lens from which this strategy is viewed, financial considerations vary.

Participant Lens

The cost of previous code enhancements is usually framed through a cost-effectiveness study. Such a study would elaborate on the costs to participants, which would primarily include the costs of updating infrastructure to meet stricter code requirements. The most recent cost-effectiveness study provided lifecycle savings to homeowners and building owners.

Implementer Lens

Inspectors and code officials may need to undergo training programs to ensure that buildings keep up with the latest codes. There may also be costs associated with conducting a cost-effectiveness study before deciding to implement changes to the code.

Equity & Environmental Justice

During CAEJC outreach, communities indicated some actions of interest that align with and have informed this strategy, including interest in natural strategies/nature-based solutions. In the long run, policy changes that improve energy efficiency may lead to an increase in equity by decreasing the overall costs of energy. However, in the short run, the initial investment in updates to be able to meet stricter building codes may be a financial burden which could disproportionately impact low-wealth communities. To ensure equitable implementation, these codes should be paired with resources specifically targeting low-wealth Pennsylvanians who live in subsidized housing, multifamily residences, or other rental properties as well as low-wealth homeowners. These include, but are not limited to, informational resources on building code changes and adequate funding to cover implementation costs.

B2. Electricity Efficiency in Buildings

Deploy electricity efficiency in existing buildings.

This strategy includes several actions to improve electricity efficiency in residential and commercial buildings. A modified framework of Act 129, which requires electric utilities to establish EE&C programs, should be offered to residents and commercial building owners to help fund electricity efficiency improvements. To support additional energy efficiency work outside of the scope of Act 129, incentive programs offered by DEP such as energy assistance programs, the weatherization assistance program (WAP), and the homeowners energy efficiency loan program (HEELP) will also drive forward electricity efficiency in the Commonwealth. These programs can be improved by increasing the savings target for utilities and removing the spending caps to allow for more comprehensive projects.

KEY METRICS

All Metrics for this strategy were included in modeling for in Strategy P1

For energy efficiency programs, there should be an increased focus on providing benefits to low-wealth and minoritized communities in coordination with the low-income usage reduction program. Metrics to determine cost effectiveness of projects should take into consideration the nationally developed cost of CO_2, CH_4, and N_2O. Energy efficiency programs should also take advantage of the funds available through the IIJA and IRA and from existing programs such as the Low-Income Home Energy Assistance Program (LIHEAP), the Low-Income Usage Reduction Program (LIURP), and the additional funds for the WAP. This funding could provide further incentives for residents and commercial property owners to take action on energy efficiency projects. The incentives from these programs should also be considered when determining the cost effectiveness of projects and is currently required of electric distribution companies (EDCs) when making their determinations regarding cost effectiveness.

Electricity efficiency can be encouraged through the establishment of building energy performance standards (BEPS) for large energy users such as commercial buildings. Support can be provided for energy audits and site assessments to collect information on where additional support can be provided. To allow for synergies with building electrification (Strategy B4) the BEPS can include carbon as a target rather than the typical overall energy usage target.

Resulting Impacts

Environmental

Reducing the quantity of electricity consumed in residential and commercial buildings reduces GHG emissions associated with electricity generation such as CO_2, CH_4, and N_2O. In addition to GHGs, reducing the volume of gas combustion also reduces criteria pollutant emissions such as NO_x, SO_x, $PM_{2.5}$, and VOCs that are ground-level ozone precursors.

Economic

Investment in electricity efficiency in buildings is expected to have a positive economic impact due to the creation of manufacturing and installation jobs to handle the increase in action on building efficiency projects.

Negative economic impacts will mostly affect the electric generation suppliers due to the reduction in electricity sales.

The financial incentives in the IRA will mitigate some of the initial economic burden for transitioning to more efficient equipment and appliances. However, over time the cost savings from reduced electricity usage will be a net benefit for those who installed more electricity-efficient systems.

Social and Health

A large positive social impact of this strategy is the reduction in energy burden as implementers of energy efficiency upgrades will require less money to receive similar, if not improved operations in their homes. To mitigate the possibility of exacerbated wealth discrepancies, this strategy should consider access to efficiency improvements for tenants and protection from implementation costs being passed onto consumers through higher energy rates.

The health impacts of this strategy are provided from the reduction of community air pollution from the reduced emissions from generation of electricity. The increase in efficiency additionally provides more access to cost-effective temperature control, reducing the health impacts from being exposed to extreme heat and cold.

RELATED FUNDING OPPORTUNITIES

Home Efficiency Rebates Program

$4.3 billion in formula grants to state energy offices will be distributed to reduce the upfront costs of whole-home energy efficiency upgrades in single- and multi-family homes. Rebates are designed to be tied to the predicted energy savings attributable to the project.

Implementation Considerations

Improving electricity efficiency, be it voluntary, through incentives and/or through a retrofit program is well established and has been bolstered by federal programs like the IRA to make action now both environmentally and economically prudent. The following actions could be taken as part of implementing this strategy:

- Reform Act 129 to allow for deeper and broader incentives for energy efficiency, which would require legislative action to accomplish. This could include providing a higher budget, adjusting the cost-effectiveness tests and period of analysis for energy expansion and expand the current programs to additional electricity distribution companies. Together these types of changes could increase EE&C and provide participants with expanded incentives to undertake EE measures. This can be done for electrical energy efficiency through increasing targets and/or removing spending caps, while maintaining a focus on providing benefits to low-wealth and minoritized communities.
- Consider utilizing the National Standard Practice Manual for Energy Efficiency (NSPM for EE), which allows states to adapt the cost-effectiveness screening tool with their needs, taking into account GHG emissions reductions and placing costs and benefits on an equal footing (https://www.nationalenergyscreeningproject.org/national-standard-practice-manual/).
- Continue to support and expand Pennsylvania incentive programs for energy efficiency including energy assistance programs, Pennsylvania's WAP and HEELP.
- Utilize existing clean energy financing tools offered by the Pennsylvania Energy Development Authority (PEDA), Community Development Financial Institutions (CDFIs), and community lenders.
- Utilize and promote programs, such as clean energy financing (e.g. Community Property Assessed Clean Energy or C-PACE), commercial building energy performance programs or other incentives and mandates to spur action from large commercial electricity consumers to invest in upgrades for equipment, appliances, and building envelopes.
- Establish BEPS for large energy users including carbon as a target rather than the typical overall energy usage target.

Energy efficiency also 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, efficient air conditioning including chillers, rooftop units and other HVAC equipment).

Partners and Participants

- **PA PUC:** PA PUC has already authorized a gas utility to conduct its own EE&C program using Act 129 criteria. PUC has similarly approved several voluntary natural gas efficiency programs for several gas utilities.
- **Pennsylvania Department of Community and Economic Development (PA DCED):** PA DCED administers the state's WAP, which facilitates increased energy efficiency in homes by conducting onsite energy audits and making the most cost-effective repairs and home upgrades to improve energy efficiency.
- **Households & building owners**: Individual home and building owners will play a role by applying for, participating in utility programs, and installing more electricity-efficient technologies in their homes, commercial retrofit, or new building projects.
- **Builders, contractors, and equipment service providers:** Providers of the services and equipment to decarbonize buildings. This group may expand over the course of measure implementation, especially due to workforce development and expansion.
- **Local energy/climate nonprofits**: Energy nonprofits such as local chapters of the US Green Building Council can participate in marketing, outreach, and education with Pennsylvania residents can increase awareness of the benefits of EE&C programs and increase demand for programs run by electricity utilities.
- **Electricity utilities:** Electricity utilities play a crucial role in implementing voluntary demand-side management programs, and those utilities that currently have such programs should continue to operate and expand on them. Utilities that do not have such programs could begin to implement them.

Financial Considerations

Depending on the lens from which this strategy is viewed, financial considerations vary.

Participant Lens

- **Voluntary measures:** Individual households and building owners can choose to voluntarily undertake electricity efficiency measures. Federal incentives, utility rebates, and grants can help reduce financial barriers to completing projects, but high upfronts are a barrier for low-income communities.
- **Programmatic**: To support rebate programs, rate payers pay into a fund which can slightly increase utility bills. The compiled fund is then used for rebates that reduce participants' net costs for electricity efficiency projects.

- **Required from legislation**: Electricity efficiency standards on equipment may limit purchase choices and lead to higher costs in meeting requirements when replacing equipment. Additionally, comprehensive building performance policies (such as the City of Philadelphia's Building Energy Performance Program) require action by building owners that can change their electricity usage.

Implementer Lens

Because many of the programs to support this measure already exist, the financial considerations will largely remain the same. Expanded implementation will result in expanded costs for implementers and expanded benefits to society.

Equity & Environmental Justice

During CAEJC outreach, communities indicated two key actions of interest that align with and have informed this strategy. Overall, energy efficiency upgrades can reduce the cost of electricity for beneficiaries, and prioritizing EJ areas for electricity efficiency upgrades for homes (especially multifamily homes) and schools that serve low-income communities can minimize the cost burden of energy.

Actions from the CAEJC Program that align with this strategy include:

- **Perform weatherization, energy efficiency upgrades, and seal exterior building elements of homes for owners and tenants.**
- **Fund energy audits and property improvements particularly for rental properties.**

The IRA and Justice40 programs are specifically aimed at providing the necessary funding to allow low-wealth and minoritized communities to take action on building energy efficiency. This allows for more comprehensive action on energy efficiency in buildings and provides a way for these communities to see the benefits of reduced energy burden, reduced indoor air pollution, and reduced air pollution in their communities.

B3. Gas Efficiency in Buildings

Deploy gas efficiency in existing buildings.

This strategy is aimed at reducing gas usage across commercial and residential buildings in the Commonwealth. Pennsylvania has seen growing action from gas utilities to provide EE&C programs with voluntary demand-response programs. With the energy market becoming increasingly customer driven, gas utilities are seeing the benefit of providing opportunities for customers to save. These types of programs should be expanded and required for all major gas utilities in the Commonwealth through legislation mirroring Act 129. In addition to this, Pennsylvania agencies including DEP and PA PUC have offered programs that assist in deploying gas efficiency projects through energy assistance programs, the WAP and the HEELP. These programs should be bolstered, and new programs and incentives should be established to reach more energy users.

KEY METRICS

GHG emissions reductions:

2030: **0.11 $MMTCO_2e$**
2050: **1.07 $MMTCO_2e$**

Cost (or benefit) per ton $MTCO_2e$/reduced): **\$58/$MTCO_2e$**

These programs should be expanded and mandated for all major gas utilities in the Commonwealth through a program set similar action to what occurs in Act 129.

This strategy also aims to take stock of major gas use in large commercial buildings to include expanded energy efficiency, pushing action on gas efficiency through equipment, appliance, and envelope upgrades through end-of-life upgrades or retro commissioning. A BEPS program utilizing carbon as a target can incentivize major gas users to be proactive in improving gas efficiency.

This strategy sets Pennsylvania up to take advantage of federal funds from IRA to help EJ areas afford equipment, appliance, and envelope upgrades, resulting in reduced emissions, reduced air pollution, and reduced energy burdens while increasing comfort.

Resulting Impacts

Environmental

Reducing the quantity of gas consumed in residential and commercial buildings reduces GHG emissions associated with gas combustion such as CO_2, CH_4, and N_2O. In addition to GHGs, reducing the volume of gas combustion also reduces criteria pollutant emissions such as NO_x, SO_x, $PM_{2.5}$, and VOCs that are ground-level ozone precursors.

Economic

Investment in gas building efficiency is expected to have a positive economic impact due to the creation of manufacturing and installation jobs to handle the increase in action on building efficiency projects. Still, existing workers within the gas industry will need skills training, availability of comparable wages, and general support in understanding how to remain employed throughout the transition.

Negative economic impacts will mostly affect the gas generation suppliers due to the reduction in gas sales.

The financial incentives in the IRA will mitigate some of the initial economic burden for transitioning to more efficient equipment, appliances, and envelopes, however over time the cost savings from reduced gas usage will be a net benefit for those who installed the systems.

Social and Health

A large social impact of this strategy is the reduction in energy burden as implementers of energy efficiency upgrades will require less money to receive similar, if not improved operations in their homes.

Positive health impacts of this strategy are provided from the reduction of both indoor and community air pollution stemming from the combustion of natural gas. Among other benefits reduced air pollution benefits health via reduced risk of asthma and by reducing effects on those with underlying conditions exacerbated by pollution. The increase in equipment, appliance, and envelope efficiency also provides more access to cost-effective temperature control, reducing the health impacts from being exposed to extreme heat and cold.

RELATED FUNDING OPPORTUNITIES

Weatherization Assistance Program

The weatherization assistance program (WAP) aims to reduce energy costs for low-income households by increasing energy efficiency. The IIJA is expanding on this program with the Enhancement & Innovation funding opportunity with a maximum award of $2 million. This represents a significant increase for the WAP.

Implementation Considerations

Improving gas efficiency, be it voluntary, through incentives and/or through a retrofit program is well established and has been bolstered by federal programs like the IRA to make action now both environmentally and economically prudent. The following actions could be taken as part of implementing this strategy:

- Implement a program similar to those resulting from Act 129 that mandates natural gas utilities to reduce direct natural gas consumption through EE&C programs and establishing annual savings targets.

- Continue to support and expand Pennsylvania incentive programs for energy efficiency including energy assistance programs, Pennsylvania's WAP, the HEELP, and LIURP.
- Create new or expand other existing programs and incentives for gas efficiency upgrades in more properties including:
  - Single, multifamily, and small commercial properties
  - Large commercial properties or other large energy users (i.e., hospitals)
  - Municipal and government buildings including schools, government buildings, and operations
- Establish programs, such as clean energy financing (building off of existing programs offered and being developed by the Philadelphia Energy Authority or PEA, CDFIs, and community lenders), commercial building energy performance programs or other incentives and mandates to spur action from large commercial gas consumers to invest in upgrades equipment, appliances, and envelopes.
- Support energy audits and site assessments to support building inventories where areas for additional support or lagging progress can be identified.
- Encourage energy rate design which incorporates the economic benefits of energy efficiency in calculation.

Energy efficiency also 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).

Improving the efficient use of electricity is also interrelated with Strategy B4 on Building Electrification, and taking an efficiency first approach may help to downsize certain electrification technologies and allow for the most cost-effective retrofits.

EXAMPLE UTILITY PROGRAM

Columbia Gas of Pennsylvania's Warm Wise Program

Columbia Gas of Pennsylvania petitioned for the implementation of an EE&C program in 2022 with the program implementation starting in July 2023. The WarmWise program has four main parts. The income eligible audit and rebates program which provides free home energy audits for an energy efficiency plan with costs savings and potentially free installation for measures, the low-income usage reduction program which helps identify ways to save and take action for free, the online energy audit and kit program, and the energy efficiency rebates program which provides cash for upgrading to qualifying furnaces, boilers, tankless water heaters, and smart thermostats.

Partners and Participants

Implementing gas efficiency programs will require significant partnership and coordination with interested parties outside of DEP. Key partners include:

- **PA PUC:** PA PUC already supports this strategy as they are currently responsible for managing the proposals and plans for utilities to implement EE&C. With legislative support, the PA PUC can build a framework for required EE&C programs for all large gas utilities in the state to help build upon the successes of current Act 129 programs.
- **PA DCED:** PA DCED administers the state's WAP, which facilitates increased energy efficiency in homes by conducting onsite energy audits and making the most cost-effective repairs and home upgrades to improve energy efficiency.
- **Gas utilities:** Gas utilities play a crucial role in implementing voluntary demand-side management programs, and those utilities that currently have such programs should continue to operate and expand on them. Utilities that do not have such programs could begin to implement them.
- **Builders, contractors, and equipment service providers:** Providers of the services and equipment to decarbonize buildings. This group may expand over the course of measure implementation, especially due to workforce development and expansion.
- **Local energy/climate nonprofits**: Energy nonprofits such as local chapters of the US Green Building Council can participate in marketing, outreach, and education with Pennsylvania residents can increase awareness of the benefits of EE&C programs and increase demand for programs run by gas utilities.
- **Households & building owners**: Individual home and building owners will play a role by applying for and participating in utility programs and installing more gas efficient technologies in their homes, commercial retrofit, or new building projects.
- **Consumer advocates and social service providers:** Equitable implementation of this strategy relies on consumer advocates and social service providers identifying and filling key gaps in program coverage and advocating for equitable rate setting.

Financial Considerations

Depending on the lens from which this strategy is viewed, financial considerations vary.

Participant Lens

- **Voluntary measures:** Individual households and building owners can choose to voluntarily undertake gas efficiency measures. With the current state of gas technologies, gas efficiency projects can take longer to payback via energy bill savings, if not paired with appropriate air sealing and weatherization improvements which can have higher upfront costs. Federal incentives, utility rebates, and grants can help reduce financial barriers to completing projects, but high upfront costs are considered a barrier for low-income communities.

- **Programmatic**: To support rebate programs, commercial and residential rate payers could pay into a fund which can slightly increase utility bills. The compiled fund is then used for rebates that reduce participants' net costs for gas efficiency projects.
- **Required from legislation**: Gas efficiency standards on equipment may limit purchase choices and lead to higher costs in meeting requirements when replacing equipment. Additionally, comprehensive building performance policies (such as the City of Philadelphia's Building Energy Performance Program) require action by building owners that can change their gas usage.

Implementer Lens

Gas utilities that implement new or expanded EE&C programs will experience costs associated with program startup or expansion planning and program administration and tracking. As a result, may need to seek additional funding to support additional hiring and program management. Gas utilities could aim to collaborate with one another for unified offerings, to share lessons learned, or reduce administrative costs by pooling program resources.

Equity & Environmental Justice

During CAEJC outreach, communities indicated three key actions of interest that align with and have informed this strategy, indicating the importance of applying it to rental properties as well as owner-occupied ones. The shift to more efficient gas equipment, appliances, and building envelopes will also increase comfort and mitigate the risks of extreme heat and cold for residents that currently struggle to or unable to afford paying increasingly high energy bills when faced with extreme temperatures. The IRA and Justice40 are specifically aimed at providing the necessary funding to allow low-wealth and minoritized communities to take action on building energy efficiency. This allows for more comprehensive action on reducing gas use in buildings and also provides a way for these communities to see the benefits of reduced energy burden, reduced indoor air pollution, and reduced air pollution in their communities. Additional considerations may include:

- Providing targeted financial assistance, beyond existing subsidies, to account for the high upfront costs associated with energy efficiency infrastructure and program startup. These upfront costs may also include necessary health and safety upgrades in buildings to ensure the safety of both occupants and the services providers who carry out installations and continued maintenance.
- Creating opportunities for job creation.
- Taking care not to have climate solutions financed through utility bills, which can play an undue burden on low-wealth communities.

Actions from the CAEJC Program that align with this strategy include:

- Perform weatherization, energy efficiency upgrades, and seal exterior building elements of homes for owners and tenants.
- Replace and/or service roofs, windows, doors; improve insulation and air sealing.
- Fund energy audits and property improvements particularly for rental properties.

B4. Building Electrification

Deploy gas and fuel oil alternatives in existing buildings.

This strategy includes deploying building electrification technologies (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 for electrification of new buildings when there are large natural gas infrastructure costs or when fuel oil is the alternative. Heat pumps are common electrification technologies, with air-source heat pumps being the most common type.

While electrification reduces onsite emissions and fossil fuel use, it does not necessarily lead to energy savings because natural gas and fuel oil reduction are often offset by an increase in electricity use. Increased electricity uses and resulting peak load demand from building electrification will impact the electricity grid, and grid updates and resiliency improvements may be needed to ensure reliable electricity supply for building use. Please see strategy P2 for more details on strategies to ensure the electrical grid reliability. Additionally, where feasible, paring electrification with efficiency (Strategy B2) and rooftop solar (Strategy B5) can help to reduce energy costs and increase grid resiliency.

KEY METRICS

GHG emissions reductions:

2030: **1.96 MMTCO$_2$e**
2050: **7.43 MMTCO$_2$e**

Cost (or benefit) per ton MTCO$_2$e/reduced): **Included in Strategy P1**

Resulting Impacts

Environmental

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 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. 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.

Economic

The electrification of residential and commercial sectors is expected to have positive impacts in the manufacturing and construction (installation) sectors. However, the costs of electrification are high, and paying for electrification will lower disposable income and expenditures in other consumption categories.

Social and Health

The health impacts of this strategy are provided from the reduction of both indoor and community air pollution that stems from the combustion of natural gas. Natural gas stoves contribute to indoor air pollution which can be alleviated through electrification of cooktops.

It should be noted that electrification must at minimum be paired with an electricity efficiency strategy to mitigate the cost of additional electricity load. This cost is an example of typical community concerns named in relation to electrification, meaning education and training on proper equipment usage should be provided when transitioning or advocating for the transition of fuels. Similarly, electrification should consider how households and businesses currently use gas-powered equipment to best communicate the benefits of and alleviate concerns about a fuel switch.

RELATED FUNDING OPPORTUNITIES

Home Electrification and Appliance Rebates

The Home Electrification and Appliance Rebates provides $4.3 billion in formula grants for state energy offices to develop and implement high-efficiency electric home rebate programs with the intent to reduce the upfront cost of efficiency electric technologies in single- and multi-family homes.

Implementation Considerations

Building electrification is supported by federal programs (such as those funded by the IRA). It is important to note that not all applications of electrification will be cost effective. Electrification of new construction is more cost effective than retrofitting existing buildings.[13] The following actions could be taken as part of implementing this strategy:

- Implement electrification *after* energy efficiency measures. This increases the effectiveness of electrification by reducing the amount of electricity wasted by inefficient appliances and leaks in building envelopes.
- Including carbon as a target of BEPS programs (instead of the typical overall energy usage target) to incentivize electrification.
- Planning for electric panel upgrades in properties to better support electrification.
- Assessment of electric grid capacity and planning any necessary expansions or upgrades to address an increase in demand across the state.

[13] Denniston, Sean. "Blog: New Study on Electrification Costs Shows Benefits to Building Owners and Society." New Buildings Institute. April 14, 2022. https://newbuildings.org/new-study-on-electrification-costs-shows-benefits-to-building-owners-and-society/.

Electrification may also include and/or require different equipment and appliances, such as:

- Heat pumps, VRFs and other HVAC equipment, which operate differently than furnaces and boilers. New equipment may run more frequently, even if it is using less energy.
- Induction stoves may require changes in cookware.
- Some HVAC systems (such as existing steam or hot water systems) may have challenges with conversions to heat pumps. In those instances*, ductless systems or hybrid systems* may be a better fit instead of electric boilers.
- In some instances, *electric resistance heating* or other backup heating may be needed.

Partners and Participants

Implementing electrification will require significant partnership and coordination with interested parties outside of DEP. Key partners include:

- **PA PUC:** PA PUC is currently responsible for managing the proposals and plans from utilities to implement EE&C, and this could be expanded to include electrification. Currently, Act 129 mandates the reduction of utility electricity sales; further legislative support would be necessary to achieve this result
- **PA DCED:** PA DCED administers the state's WAP, which facilitates increased energy efficiency in homes by conducting onsite energy audits and making the most cost-effective repairs and home upgrades to improve energy efficiency and expand electrification.
- **Electricity utilities:** Electricity utilities play a crucial role in implementing voluntary demand-side management programs and could play a similar role in electrification programs by expanding on their existing work.
- **Builders, contractors, and equipment service providers:** Providers of the services and equipment to decarbonize buildings. This group may expand over the course of measure implementation, especially due to workforce development and expansion.
- **Local energy/climate nonprofits**: Energy nonprofits such as local chapters of the US Green Building Council can participate in marketing, outreach, and education with Pennsylvania residents can increase awareness of the benefits of electrification programs and increase demand for programs.
- **Households & building owners**: Individual home and building owners will play a role by applying for and participating in utility programs and installing more gas efficient technologies in their homes, commercial retrofit, or new building projects.
- **Consumer advocates and social service providers:** Equitable implementation of this strategy relies on consumer advocates and social service providers identifying and filling key gaps in program coverage and advocating for equitable rate setting and coverage of upfront costs.

Financial Considerations

Electrification is not always cost saving, and, in some cases, new electric equipment will cost more than the operation of previous gas equipment. Implementation should be careful to balance these financial considerations and focus on beneficial electrification, where existing equipment allows for cost savings through adoption.

Participant Lens

In some cases, large electrification projects may require changes to home or building infrastructure including upgraded service, new breaker panels or other related work. This can add to costs for property owners that decide to participate in electrification upgrades. Costs may also overlap with those for EV charging infrastructure and other infrastructure needed in facilities.

Large commercial buildings may be challenged to use certain electrification technologies. Retrofitting existing commercial buildings designed for fossil fuel-based technologies can be complex and costly particularly for older buildings which rely on steam or water sources for heating.

Implementer Lens

Some electrification technologies may require training for contractors to deploy and maintain them more effectively. Similarly, building operators of commercial facilities will need to be trained in maintaining this equipment. Cost reductions in technologies and gains in energy efficiency are critical to the adoption of electrification. Energy efficiency is a key enabling mechanism for the financial feasibility of electrification. See strategy B2 for more details.

Equity & Environmental Justice

Though not directly mentioned by communities in outreach during the CAEJC, electrification is a key energy property improvement that can support both renter and owner-occupied properties. Electrification may result in the creation of job opportunities, and local communities can benefit from well-paid, high-quality jobs that arise from these programs. There are considerable equity considerations, especially for those applications of electrification are slower to realize financial savings. Equitable implementation should include consideration of the financial implications for EJ areas. Considerations may include the following:

- Even beyond subsidies for high upfront costs, solutions may need to provide bill assistance.

Action from the CAEJC Program that aligns with this strategy:

- Fund energy audits and property improvements particularly for rental properties.

- Increased electrification may not just result in changes to onsite equipment, but may require system-wide electricity generation, transmission, and distribution improvements. Costs for these improvements will need to be borne equitably/supported by other funding sources.
- Residences in EJ areas are more likely to require building health and safety upgrades to allow electrification work to occur safely. This would increase the upfront costs associated with this strategy.
- As previously noted, energy efficiency needs to also be deployed in addition to electrification to lower energy costs overall.
- Take care that climate solutions do not result in significant utility rate changes, which could negatively impact energy users bills. This can result in inequitable distribution of the energy burden for improved climate outcomes.

B5. Onsite Solar

Deploy onsite solar, distributed energy resources, and battery systems in buildings.

This strategy includes the installation of onsite distributed solar photovoltaics and storage in both the residential and commercial sectors, covering everything from single-family homes and shopping centers to schools and local government buildings. Distributed solar and energy storage play an important part in the decarbonization of the electricity supply by expanding the amount of renewable energy sources and contributing to a more decentralized and resilient electric grid system.

Onsite solar implementation will align with the grid decarbonization strategies outlined in strategy P1. To maximize the benefits of this strategy, use of solar, storage and other distributed energy resources must expand across the Commonwealth.

KEY METRICS

All Metrics for this strategy were included in modeling for in Strategy P1

Resulting Impacts

Environmental

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. This is because onsite solar generation reduces emissions from larger, grid-scale fossil-fueled power plants, including the associated emissions from line losses incurred in transmitting the electricity over great distances to the consumer.

Economic

The installation of onsite distributed solar and energy storage systems is expected to have positive economic impacts. Some positive impacts result from growth in manufacturing and installation jobs, because of distributed energy investments, but most of the positive impacts result from energy bill savings for households and business owners. While there is some initial investment, significant bill savings will accrue over time, resulting in additional cost savings potential in later years.

Social and Health

Investments in solar and storage can increase reliability and resilience in the face of climate induced weather events. This reliability will better ensure systems, including backup batteries and generators, will function at times of extreme need, particularly for those with temperature sensitivities and medical equipment needs. To achieve reliability in this area, this strategy must also include education on how to maintain and best utilize unfamiliar equipment.

Solar can be used as a function of reliability, but current infrastructure and policy create a discrepancy in rollout possibilities. Impact will be more accessible for those living in owner-occupied single-family homes, while Pennsylvanians in multifamily homes will experience barriers in decision autonomy and equipment affordability, including access to loans and other financing.

Implementation Considerations

The following actions could be taken as a part of implementing this strategy:

- To deploy and scale onsite solar, buildings may have additional infrastructure needs (including updates to the roof or electrical work).
- Grow education of solar and storage system. There is a misconception that solar without appropriate storage can still power a home. Also, proper education is needed on their interaction and on the use and limitations of storage.
- Encourage the installation of distributed generation and storage system on new and existing properties by providing incentives to homeowners and building owners completing infrastructure improvements to be ready for onsite renewable energy deployment.
- Revising or supporting local governments to amend rules such as local zoning or permitting to encourage better adoption of solar and energy storage projects.
- Building on existing comprehensive planning efforts as developed in the Finding Pennsylvania's Solar Future[14] plan.
- Expand the solar carve-out in the Pennsylvania AEPS.

RELATED FUNDING OPPORTUNITIES

EPA's GGRF - Solar for All Program

Solar for All is a $7 billion program aimed at expanding solar in low-income and disadvantaged communities. PEDA has received a notice of award from the EPA for $156 million to deliver solar projects, provide technical assistance, and develop a solar workforce.

[14] "Pennsylvania's Solar Future Plan." PA DEP. n.d. https://www.dep.pa.gov:443/Business/Energy/OfficeofPollutionPrevention/SolarFuture/Pages/Pennsylvania's-Solar-Future-Plan.aspx.

Partners and Participants

- **PA PUC: PUC** has established interconnection standards and requires approval for net metering requests when they are 500 kW or greater in size. There is currently not a clear direction for interconnection rules for storage, which would help streamline renewable energy deployment.
- **DCNR**: DCNR has developed guidance on solar siting, entitled Conservation Considerations for Siting, Planning, and Maintaining Grid-Scale Solar Systems in Pennsylvania.
- **PEDA:** PEDA has received a notice of award from the EPA's Solar for All program to expand solar to low-income and disadvantaged communities. PEDA could play a broader role in financing onsite renewable energy in the Commonwealth.
- **Utilities:** Solar rules largely already exist but can be streamlined. Additionally, as more and more systems are installed, grid infrastructure may need investments to keep up with generation capacity.
- **Local Governments:** Local governments and their supporting agencies can streamline the permitting and development of energy generation and storage projects. Local zoning laws (especially those prohibiting structures above certain heights, therefore wind turbines), can be major barriers to renewable energy development in the residential and commercial sector.
- **Solar and storage installers:** There will continue to be a growing demand for a skilled solar and storage installation workforce.
- **Private sector and building owners:** Property owners and tenants must participate in developing small-scale renewable energy operations to reap the financial and environmental benefits of their investments.

Financial Considerations

Depending on the lens from which this strategy is viewed, financial considerations vary.

Participant Lens

Range of solutions exist for implementation (purchase, finance, power purchase agreement [PPA], lease). Consumer education and financial education are needed to help folks navigate and understand the options available to them.

Implementer Lens

There may be federal funding available to scale the technologies prioritized in this strategy. Pennsylvania has already pursued funding from EPA's Solar for All program as part of the Greenhouse Gas Reduction Fund. As part of this program, Pennsylvania has pursued projects and sought to lead by example in renewable energy adoption by prioritizing installing onsite solar on public buildings and land.

The Commonwealth could apply for and utilize this funding to scale the activities needed to implement this strategy. The implementation of new distributed solar has been discussed extensively in Pennsylvania's Solar Future Plan, which includes a full set of technology support options including financing, workforce development and potential incentives.

Equity & Environmental Justice

Though not directly mentioned by communities in outreach during the CAEJC, onsite solar and storage is a key energy property improvement that can support both renter and owner-occupied properties. Community-scale solar was specifically mentioned and could be supported onsite at community centers or rental properties, given legislative updates (See *Chapter 7: Legislative Recommendations).* Overall, this strategy supports solar energy for communities and has considerable equity considerations for implementation, including of:

- There are a range of different ways to install solar (purchase, financed, PPAs, leases). To ensure equitable implementation of this strategy, administrators will need to ensure that the enabling structures do not create undue financial burden on utility customers in EJ areas.
- Mechanisms will need to be considered to ensure that savings realized by solar energy installations on rental properties can be passed on to tenants. This is of particular importance for low-income and heavily energy burdened renting communities.
- Installing energy efficiency upgrades in addition to solar will help ensure lower overall energy costs. As discussed in strategy B2, this is critical in disadvantaged communities.
- Onsite solar installation creates job opportunities. When considering equitable implementation, administrators can prioritize a local workforce and create partnerships with high schools in communities impacted by EJ issues for training programs. Additionally, training programs could target the existing fossil fuel energy workforce who already have some technical experience.
- Storage can create resilience opportunities which can benefit communities by providing a more stable energy supply. It is important to ensure that communities impacted by EJ issues have equitable access to these resilience benefits.

Action from the CAEJC Program that align with this strategy include:

- Fund energy audits and property improvements particularly for rental properties.
- Support physical and policy infrastructure for solar energy sources at a community scale.

Transportation Sector

The transportation sector encompasses all activities that facilitate the conveyance of people and goods, while providing a wide range of services. In 2020, the latest inventory year for Pennsylvania, the transportation sector was 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, even as the number of cars on the road and trips taken has increased. Despite this broader trend, over the past few years, transportation emissions had been increasing slightly in Pennsylvania, but as the COVID-19 pandemic significantly disrupted transportation patterns throughout the United States in 2020, emissions from this sector were about eight $MMTCO_2e$ lower than observed emissions in 2019. As the effects of the pandemic have waned, 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.

In 2021, more than 102 million vehicle miles were traveled in Pennsylvania.[15] Transportation is vital to Pennsylvania's economy, contributing to the regional economy and helping residents move from place to place. Throughout the Commonwealth there are more than tens of thousands of miles of roads, thousands of bridges and an assortment of other infrastructure supporting transportation.

[15] "State Energy Profile Data." US EIA. https://www.eia.gov/state/data.php?SID=PA.

Strategies

The strategies proposed to address transportation emissions reflect current technological and policy trends of lowering fuel consumption through vehicle miles traveled (VMT) reductions and alternative vehicle technologies and trends of lowering the carbon intensity of the fuel consumed. Taken together, these approaches can significantly lower GHG emissions and other air pollutants. Four strategies are modeled, and results indicate that, together, they will reduce emissions compared to the BAU in 2030 and 2050 (see Table 12).

Table 12. Transportation sector GHG reduction strategies and associated reductions ($MMTCO_2e$)

GHG Reduction Strategy	2030	2050
T1. Transit & Multimodal Improvements	1.27	1.88
T2. Light-Duty Vehicle Electrification[a]	0.92	13.86
T3. Zero Carbon Medium- & Heavy-Duty Vehicles[a]	0.76	11.49

[a] A portion of GHG reduction from this strategy is captured in the electricity generation sector.

For each strategy, the environmental 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 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.

Lower Carbon Materials

PennDOT sees potential in exploring the use of lower carbon materials as a priority initiative. This endeavor would further reduce Pennsylvania's carbon footprint by integrating sustainable materials into statewide infrastructure. PennDOT continues to coordinate with key construction industry organizations and material suppliers to identify strategies. Examples of materials with lower carbon emissions include, but are not limited to, asphalt mixtures with reclaimed asphalt pavement, asphalt mixtures produced at lower production temperatures, asphalt mixtures utilizing other recycled content, asphalt materials produced through improvements in the production process, concrete pavements with the ability to reabsorb CO2 through a carbonation process, and concrete materials that utilize Type 1L cement. Some of these strategies may also be coordinated with other programs, like the Federal Buy Clean Program. PennDOT will continue to evaluate these opportunities and provide more guidance to Districts and MPOs/RPOs.

Equity in the Transportation Sector

Accessibility: Accessibility in the transportation sector primarily refers to affordability, proximity to, availability of, navigability of, and reliability of public infrastructure, disability-oriented services, and workforce development. EVs are still financially inaccessible to the majority of low-income Pennsylvanians. This is true both for the purchase and maintenance of EVs, as many mechanics local to EJ areas need opportunities to train and develop EV-maintenance skills.

Advocacy: Efforts should particularly consider impacts on those in close proximity to transportation pollution, those who rely on public transportation to meet key needs, and those with additional EV adoption barriers related to finances and infrastructure access.

Accountability: Budgets should reflect a balance of efforts that allow efficient lowering of GHGs while expanding access for new transit services

T1. Transit and Multimodal Improvements

Expand transit, transit-oriented design, and multimodal transportation.

This strategy aims to reduce emissions from the transportation sector by reducing VMT for passenger vehicles in Pennsylvania. It aims to provide other robust modes of transportation that are not only used alongside passenger vehicles, but ultimately become the default option instead of passenger vehicles.

There is no "one-size-fits-all" solution to reduce VMT. Modes of transportation other than personal vehicles are highly dependent on population density, local topography, existing infrastructure, demographics, and even weather. As such, solutions must be tailored at the local level to meet the specific needs of each community. Paired with land use and development policies, efforts to incentivize sustainable transportation modes (e.g., walking, biking, transit) in urban areas, to expand multimodal options outside urban areas (e.g., broader transit options, carpool), and to optimize when travel does occur (e.g., through telecommuting, trip consolidation) will reduce VMT.

KEY METRICS

GHG emissions reductions:

2030: **1.27 $MMTCO_2e$**
2050: **1.88 $MMTCO_2e$**

Cost (or benefit) per ton $MTCO_2e$/reduced: **-$152/ $MTCO_2e$**

Pennsylvania already invests significant funding in transit options across the state; in FY 23-24 the state invested over $1.7 billion in-state funding along with $500 million in federal funding into transit solutions and maintenance. These funding opportunities include improvements to rural transit services, interstate passenger rail, bike and pedestrian infrastructure, and more. To expand these efforts, Pennsylvania can take advantage of IIJA grant programs like the Congestion Mitigation and Air Quality Improvement Program or the Transportation Alternatives Set Aside from the Surface Transportation Block Grant Program, which provide funding for a variety of projects from public transit charging equipment to shared micromobility (e.g., bikesharing) to constructing bike and pedestrian infrastructure.

Resulting Impacts

Environmental

Reducing the number of miles driven by passenger vehicles in Pennsylvania will reduce the GHG emissions associated with gasoline and diesel combustion such as CO_2, CH_4, and N_2O. In addition, reducing the volume of gasoline and diesel combustion also reduces criteria pollutants such as NO_x, SO_2, VOCs, $PM_{2.5}$ and PM_{10}.

Economic

Similar to T1, reducing VMT will reduce gasoline and diesel consumption, saving Pennsylvanians money at the pump. Driving less will also help drivers save on maintenance costs. With a more robust public transportation system and pedestrian- and bike-friendly streets, larger savings are possible by reducing reliance on owning a vehicle entirely. The lower the costs of public transit, the more people can expect to save from using it instead of driving. With less travel, however, gasoline stations, rest stops, and repair shops may see less business.

Social and Health

Efforts to reduce VMT will result in more mobility options for those who are unable to own or operate a vehicle. Reducing the criteria air pollutants that result from gasoline and diesel combustion will also improve air quality and reduce the burden of health issues associated with these air pollutants. This will be especially true for communities near highways or major roadways that are disproportionately impacted by vehicle air pollution.

In addition, reducing VMT reduces congestion and ultimately leads to a safer and more pleasant experience for all who use the road. Shifting VMT to active transportation modes like biking and walking will also have a positive impact on public health by increasing exercise. When paired with nature-based land management solutions, utilizing active transportation modes can improve wellness through access to nature and cleaner air. Expanded public transportation options can also result in better social cohesion and community access to resources and services,

Implementation Considerations

While public transit and multimodal options are already offered in the state, the state can reduce the cost to use these options and improve their convenience and reliability to make them a more attractive option than driving. Support for the development of new facilities, infrastructure, vehicles, and associated enabling work for public transportation and multimodal improvements can take many forms including clean energy financing tools, incentive programs, comprehensive planning efforts, and revisions to permitting and zoning.

The state will need to coordinate with regional and local transportation agencies, metropolitan planning organizations (MPOs), and other local interested parties to implement this strategy. Work has been done through PennDOT's 2045 Long-Range Transportation Plan (LRTP) prioritizing safety, equity, accessibility, and climate resilience in the shift from single passenger vehicle travel. Actions to support this strategy

RELATED FUNDING OPPORTUNITIES

Surface Transportation Block Grant

The Surface Transportation Block Grant Program (STBG) is designed to promote flexibility in State and local transportation decisions and allow for the construction of transit and active transportation on the road system. This grant represents between $13 and $15 billion annually across the US with 10% of the funds set aside for transportation alternatives.

from the plan along with additional actions to improve transit and active transportation include the following actions:

- Increase the number and/or frequency of public transit stops.
- Increase the efficiency and reliability of public transit by ensuring that buses and trains arrive on time. For accountability, easy reporting of issues, and consumer trust, establish a PennDOT-wide transit app for users to find nearest routes and timetables.
- Designate bus lanes in high-traffic areas or during high-traffic times of day, so that bus travelers may avoid traffic congestion.
- Close PA trail gaps that support vital transportation corridors.
- Create more equitable connections between public transit and parks/trails.
- Establish or expand programs to reduce transit fares for low-income transit customers.
    - Expand Philadelphia's Zero Fare pilot program, which supports free Southeastern Pennsylvania Transportation Authority (SEPTA) transit for residents living near or below the poverty level, to include Philadelphia's full population and/or other cities in Pennsylvania.
- Improve and/or establish protected bike lanes where possible, to ensure that biking remains safe, easy, and unintimidating. Improve signage and traffic lights to keep bicyclists safe.
- Subsidize bikeshares, especially electric bikeshare programs, which are already well established in urban areas of the state.
- Improve the safety and desirability of micromobility via adequate, smooth, and regularly maintained sidewalk space for pedestrians, and protected bike lanes where possible.
    - Advertise PennDOT's Bicycle Routes Map, so commuters and recreators know about trails, paths, and roads to bike within their cities and across the state.
- Improve safety, cleanliness, and security for public transportation, including transit stops, platforms, and trains or buses themselves.
- Communicate and promote each of these implementation strategies. Conduct outreach, education, and community involvement so that transit expansion is tailored to the needs and interests of communities.

Partners and Participants

Small projects such as the creation of bike lanes or 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.

Interested parties in transit expansion include:

- **PennDOT**: With insight into all public transit and transportation infrastructure, PennDOT may help fund transit expansion, transit-oriented design, and multimodal transportation options. PennDOT's 2045 LRTP is already aligned with this strategy, with express priority on safety, equity and accessibility, and climate resilience.
- **MPOs and Regional Planning Organizations (RPOs)**: MPOs and RPOs are local planning organizations which evaluate regional transportation system performance, assess resources required for improvements, and liaise with PennDOT for intrastate projects.
- **Statewide housing and development departments:** Agencies like PA DCED and the Philadelphia Housing Authority may help plan for transit stops in residential neighborhoods and facilitate placement of public or otherwise affordable housing near transit hubs, so that access to transit is not dependent on economic status.
- **Public Transportation Operators:** SEPTA, PRT (Pittsburgh Regional Transit), and other public transportation providers throughout the state are crucial to both improving transit and connecting transit to multimodal hubs.
- **Local governments and municipalities:** Are responsible for land use planning and comprehensive planning; transportation planning, development, and operations; and coordination with program development, administration (e.g., travel demand management programs), and other local policies. Their decisions shape the effectiveness of local transportation options, impacting key determinants like sidewalk safety and accessibility of transit stops.
- **Private sector partners:** Private sector partners, such as landowners, developers, and businesses play a key role in development decisions and design that affect the viability of using alternatives to driving. For example, private landowners and developers can impact the locations of bus stops or other transit access options. Businesses can also implement telecommuting policies and other policies that help manage travel demand.
- **Consumer advocates and social service providers:** Equitable implementation of this strategy relies on consumer advocates and social service providers identifying and filling key gaps in transit coverage and multimodal offerings and advocating for equitable rate setting, transit access, and safety precautions.

Financial Considerations

Depending on the lens from which this strategy is viewed, financial considerations vary.

Participant Lens

- **Voluntary measures:** Commuters and travelers within Pennsylvania elect to take public transit and incur the cost associated. Barriers to ride may include fees, inconvenience, or duration of trip compared to other options like driving or walking. Expanding the frequency, geographic accessibility, affordability, and pleasantness of transit will lower the barrier to use.
- **Programmatic:** Subsidizing cost to ride transit as well as bikeshare programs will enable greater accessibility and appreciation of transit as a public service.
- **Required from legislation:** Expanding public transit will incur costs for the state which not be sufficiently met by fees to ride, including project initiation, operations, and regular maintenance.

Implementer Lens

There may be federal funding available for the transit planning priorities outlined in this strategy. The Commonwealth could apply for and utilize this funding to implement this strategy.

Implementing large-scale transit updates may modify commuting paths and affect Pennsylvanians' day-to-day routines. Care must be taken to inform the public of transit modification and expansion plans.

Actions from the CAEJC Program that align with this strategy include:

- Increase access for individual transportation options and improve multi-use traffic areas and safe sidewalks that incorporate complete streets models.
- Connect existing and new public transportation options to activity centers.

Municipal and statewide transportation departments that implement new or expanded transit programs will experience costs associated with program startup, planning, administration, and construction. As a result, these departments may need to seek additional funding to support additional hiring and program implementation.

Equity & Environmental Justice

Investment in public transit and transit options often directly benefits low and moderate-income (LMI) individuals, who are statistically more likely to use transit. Such investments were identified as areas of interest for communities facing EJ issues, during outreach conducted by the CAEJC program. LMI communities and individuals may be neglected by public transit systems with high costs to ride, limited hours of service, or distance from work or residential centers. These pose particular issues for LMI individuals who work jobs that have rigid schedule and/or hours outside of typical commuting hours. Increasing public transit opportunities should address these existing barriers and improve the physical accessibility and affordability of transit. Safety and accessibility of multimodal areas should also be considered. Expanded transportation options for individuals with mobility aids can connect them with their communities and more economic opportunities. Equitable transit-oriented design should consider locating public housing or otherwise affordable housing near transit hubs.

T2. Light-Duty Vehicle Electrification

Deploy electric vehicles and associated infrastructure.

KEY METRICS

GHG emissions reductions:

2030: **0.92 $MMTCO_2e$**
2050: **13.86 $MMTCO_2e$**

Cost (or benefit) per ton $MTCO_2e$/reduced): **\$296/$MTCO_2e$**

This strategy aims to transition conventional light-duty internal combustion engine vehicles (ICEVs) to EVs. Sales of light-duty EVs have increased significantly in recent years as a result of factors like reduced capital costs, increased financial incentives, and increased charging availability. In 2022, EV made up 3% of passenger vehicle sales in Pennsylvania. PennDOT's electric vehicle mobility plan[16] provides a guide for transitioning light-duty vehicles.

As part of this strategy, Pennsylvanians can leverage federal funding from IRA in the form of rebates and tax credits when purchasing both new and used EVs. IRA also provides tax credits for at-home EV charging equipment in rural or low-income communities. Pennsylvania will also receive $171.5 million over five (5) years from the BIL's National Electric Vehicle Infrastructure (NEVI) Formula Program to build public EV charging infrastructure. The NEVI Formula Program has already funded fast charging stations across the state over several rounds of initial funding. Beyond taking advantage of federal funds directly, Pennsylvania will continue to publicize federal tax credits that encourage the manufacture and purchase of light-duty EV.

Resulting Impacts

Environmental

Transitioning ICEVs to EVs eliminates tailpipe emissions from each vehicle. This reduces GHGs like CO_2, CH_4, and N_2O that result from burning gasoline and diesel as well as reducing criteria air pollutants like NO_x, VOCs, $PM_{2.5}$ and PM_{10} found in vehicle exhaust, improving local air quality. Even though an increase in EVs will result in increased electricity consumption, mile-for-mile, the additional electricity generated will result in lower GHG emissions than burning gasoline or diesel to drive. This difference is even greater if the electricity is generated from renewable sources.

[16] "Pennsylvania State Plan for Electric Vehicle Mobility." PennDOT. 2022. https://www.penndot.pa.gov/ProjectAndPrograms/Planning/EVs/Documents/EVMobilityPlan.pdf.

Economic

Recent declines in the production costs of EV batteries have reduced the capital cost of passenger EVs, making them more accessible to purchase. A significant economic benefit of EVs is a reduction in annual fuel and maintenance costs. In most cases, mile-for-mile, the cost of electricity to charge and EV is considerably lower than the cost of gasoline or diesel to fuel an ICEV. With fewer moving parts, EVs also require less maintenance than ICEVs, freeing up more money in consumers' pockets for other expenditures.

A consequence of lower maintenance requirements for EVs compared to ICEVs, however, is a reduction in conventional vehicle maintenance and repair jobs. This will require workforce retraining but also provides an opportunity to develop a workforce for charging infrastructure and maintenance to avoid a net loss of jobs.

Social and Health

Reducing local criteria air pollutants by eliminating vehicle tailpipe emissions will reduce health issues associated with these pollutants, especially in communities located near highways or major roadways. On the other hand, the additional electricity generation may increase criteria air pollution in communities near fossil fuel plants. However, as fossil fuel electricity generation is phased out and replaced with renewable generation sources, criteria air pollution from increased electricity generation will pose less of a risk in these communities.

Passenger EVs also provide resilience benefits as a form of electricity storage. Electricity from an EV battery could be used to power a home during a blackout or serve as a means to stabilize the electric grid at times when electricity demand is high. These concepts, known as vehicle to home (V2H) and vehicle-to-grid (V2G), respectively, are areas of ongoing research and piloting programs to understand best regulatory structures.

RELATED FUNDING OPPORTUNITIES

Electric Vehicle Tax Credits

Qualifying Plug-In EV or fuel cell electric vehicles can provide a credit up to $7,500. This credit is dependent on if the vehicle meets critical minerals requirements and battery component requirements. Vehicles meeting only one will receive a $3,750 credit.

See fueleconomy.gov for more details on available EV tax credits.

Implementation Considerations

Current barriers to EV adoption include higher capital costs compared to ICEVs, concerns about limited range, and lack of awareness of model variety and economic incentives to choosing EVs. In addressing each of these concerns, Pennsylvania may more effectively expand EV deployment. The following actions could be taken as part of implementing this strategy:

- Establish fast public charging (Level 2 or Direct Current [DC]) for EVs and ensure that it is frequent and easily accessible along highways. A reasonable availability goal is to have chargers ("charging corridors") every 50 miles, each less than five miles from the highway. Increased presence of public charging can help reduce range anxiety and increase perception of EV ownership as convenient and worry-free.
- Seek out landowners, federal properties, and business owners who are close to highways that may be interested in hosting charging stations.
- Reduce capital costs through statewide rebate or tax credit programs complementing federal incentives for both EVs themselves and home chargers. Home chargers also include upfront costs for purchase, installation, and "make-ready," or the need to upgrade wiring and other technical specs of the vehicle; reducing such costs may ease deployment.
- Increase public familiarity and knowledge of EVs, such as existing model varieties, charging station locations, and incentives and available rebates.
- Establish statewide EV light-duty vehicles (LDV) sales goals, and publicly report on progress.
- Incentivize businesses, government entities, and other landowners to install public charging stations.
- Continue implementation of DEP's Alternative Fuel Vehicle (AFV) Rebate and Alternative Fuels Incentive Grant (AFIG) Program. See the callout box for more details.
- Collaborate with utilities to ensure the grid can handle loads from charging. Managed network charging could help reduce peak loading. Utilities can also consider electric distribution system planning, beneficial rate design, and investment in "make-ready" charging infrastructure.
- Implement the strategies identified in Pennsylvania DEP's EV Roadmap.
- Conduct outreach and education, particularly to small and/or minority-owned businesses to communicate the available tax credits, rebates, and other financial incentives and opportunities related to fleet electrification.

DEP FUNDING OPPORTUNITIES

Alternative Fuel Vehicle (AFV) Rebates for Consumers:

• Offers rebates through June 2025
• New and one-time pre-owned battery electric cars and trucks qualify, and the amount is dependent on income levels;
• Ex. A family of two (2) with a household income of $60,000 is eligible for a $3,000 rebate for a battery electric vehicle, while a family of two (2) with a household income of $25,000 is eligible for a $4,000 rebate.
• Plug-in hybrid cars and trucks qualify for a $1,500 rebate
• Other alternative fuel vehicles, and electric motorcycles, qualify for a $500 rebate.

Alternative Fuels Incentive Grant (AFIG) Program:
• Provides financial assistance and information on alternative fuels, alternative fuel vehicles, hybrid vehicles, anti-idling technologies that use alternatives to diesel fuel for heavy-duty trucks, and advanced vehicle technology research, development, and demonstration.
• Eligible applicants include schools, municipalities, counties, cities, corporations, partnerships, and nonprofits incorporated or registered in PA.

Partners and Participants

Key partners include:

- **PA DEP and PennDOT**: Encourage and facilitate the transition to clean fuels.
- **Automakers**: Car manufacturers must be able to sell EVs in the state.
- **Car buyers and lessors:** Consumers must be aware of LDV EV models, and of their access to charging stations.
- **Electric utilities:** Electrical infrastructure needs to be robust enough, especially for DC fast charging, to transport all the power needed. Also, utilities can get involved in managing networked charging to reduce loads where possible.
- **PA PUC**: PA PUC has completed a handful of initiatives to support EV infrastructure development, encourage EV adoption, and optimize grid resources. See the callout box for more details.

Financial Considerations

Depending on the lens from which this strategy is viewed, financial considerations vary. For expansion of public charging, the chargers will be publicly or privately purchased and operated. The state could incentivize private development of charging stations. EVs and home chargers are growing more affordable. Federal tax credits exist, but EV deployment must increase outreach and education to consumers to make sure there is broad awareness of tax credits and how to access them. The state may implement its own tax credits and/or rebates, and accompanying outreach and education programs, for widespread adoption.

PA PUC ONGOING EV WORK

Providing regulatory clarity for third-party sales of electricity by approving a policy allowing dynamic rates for EV charging stations.

Supporting EV Charger/TOU/Charging Pilot Programs that:

- Build publicly available and workplace accessible DC fast charging;
- Provide investment in DC fast chargers and financial incentives for Level 2 charging stations;
- Incentivize overnight charging to optimize grid and generation capacity;
- Provide necessary infrastructure for public EV charging stations without customer contribution; and
- Include pilots for public, workplace, and multi-unit dwelling charging, fleet and transit charging, and consumer education and engagement.

Supporting EV Charging Rate Designs that:

- Encouraged EDCs to consider TOU rates to facilitate EV deployment;
- Convened a stakeholder working group for EV charging rate design; and
- Proposed a Policy Statement for EV charging rate design.

Participant Lens

- **Voluntary measures:** Light-duty EVs up front purchase costs, and/or costs to install home or business refueling infrastructure, results in greater initial expense than purchasing a comparative ICEV equivalent. To overcome this expense, purchasers must realize the savings through anticipated operational fuel, maintenance, and convenience savings over the vehicle's lifetime. Consumers must be willing to spend more up-front on fuel-efficient vehicles or pursue rebates that enable or incentivize spending on EVs.
- **Programmatic:** Subsidies or tax rebates for individuals buying light-duty EVs, as seen in California, will require investment and administrative oversight from the state.
- **Required from legislation**: If the state requires that only zero emission vehicles (ZEV) LDVs may be sold in the state after a certain year, following similar policies in California (California Department of General Services - Purchasing Mandate 4121), consumers may face limited choice and higher vehicle costs.

Implementer Lens

There may be a mix of public and private ownership and funding of public charging stations. Private implementers will want to seek funding from public sources or from electric utilities. Utilities will need a supportive regulatory environment to deploy electrification efforts.

Equity & Environmental Justice

Equitable deployment of EVs and associated infrastructure requires the availability of charging infrastructure in EJ areas, thoughtfully deployed to meet community needs without displacing resources. Rebates or incentives for EV adoption could be income-dependent, enabling lower-income individuals to consider purchasing an EV where cost would otherwise inhibit them. Similarly, rebates, government-offered assistance, and readily available public guidance on installing EV infrastructure in one's own home will aid the transition to EVs.

EV deployment may be paired with other electric micromobility options with lower costs and lower barriers to entry, such as electric bikes and expanded transit, could also benefit low-wealth communities. This is especially true for communities for whom the price of car ownership is prohibitive and before EV become common on the used car market. This strategy will also mitigate existing air pollution from internal combustion engines and aligns directly with the pollution mitigation priorities of EJ areas, as identified by outreach conducted in the CAEJC program.

Action from the CAEJC Program that aligns with this strategy:

- Mitigate existing sites and sources of air and water pollution.

T3. Zero Carbon Medium- and Heavy-duty Vehicles

Implement a low-carbon fuels standard and deploy zero carbon medium- and heavy-duty vehicles and associated infrastructure.

In 2020, Pennsylvania joined 14 other states and the District of Columbia in signing a joint memorandum of understanding (MOU) committing to accelerating adoption of zero carbon medium- and heavy-duty vehicles (MHDVs). The MOU aims for 30% and 100% of MHDV sales to be ZEVs by 2030 and 2050, respectively. Modeling for this strategy reflects this goal.

Zero carbon MHDVs are emerging technologies, and research and development are ongoing to improve existing models and reduce capital costs. The modeling assumes a combination of battery electric, hydrogen fuel cell, and plug-in hybrid EV will be used to achieve the MOU goal. For light- and medium-duty vehicles, as well as for some shorter distance heavy-duty vehicles, electrification would be the most impactful decarbonization method, but for long-distance heavy-duty vehicles, hydrogen may play a larger role in decarbonization.

KEY METRICS

GHG emissions reductions:

2030: **0.76 $MMTCO_2e$**
2050: **11.49 $MMTCO_2e$**

Cost (or benefit) per ton $MTCO_2e$/reduced): **-$45/$MTCO_2e$**

Pennsylvania can take advantage of IIJA and IRA funds for installing charging infrastructure and replacing conventional MHDVs with ZEV. EPA's IRA-funded Clean Heavy-Duty Vehicle Program will provide funding for purchasing zero emission MHDVs, building out supporting infrastructure, and developing workforce training and other planning and technical activities. Pennsylvania will also encourage the adoption of zero emission MHDVs by reducing manufacturing, capital, and infrastructure installation costs. This could include tax credits or rebates for vehicle purchases, leveraging federal incentives for clean hydrogen production, and incentivizing networked MHDV charging. Hydrogen supply, ideally of the cleanest and lowest emissions variety, must be readily available across refueling stations for effective deployment of hydrogen fuel cell EV (FCEVs) and resulting emissions reduction.

Resulting Impacts

Environmental

Battery electric MHDVs have no tailpipe emissions, and the only tailpipe emission from hydrogen fuel cell MHDVs is water vapor. As a result, transitioning conventional MHDVs to ZEV reduces GHGs like CO_2, CH_4, and N_2O, as well as harmful criteria air pollutants, improving local air quality. As discussed in T3, additional electricity generated to charge electric MHDVs will result in lower GHG emissions than burning gasoline or diesel for these vehicles, mile-for-mile. However, for hydrogen fuel cell MHDVs to significantly contribute to GHG emission reductions, the hydrogen fuel needs to be produced with little to no net GHG emissions. The most significant reductions will result from using "green hydrogen," or zero carbon hydrogen produced by splitting water molecules into hydrogen and oxygen using renewable electricity (a process known as electrolysis). See strategy F3 for more details about the emissions impacts of using hydrogen fuels.

Economic

The recent decline in prices for light-duty EVs suggests that the costs of zero emission MHDVs could follow a similar trajectory. Recent research has suggested that zero emission MHDVs could reach cost parity with conventional MHDVs within a decade or so[17]. As with light-duty EVs, zero emission MHDVs will cost less to fuel and maintain than conventional MHDVs. Reduced air pollution will reduce associated medical expenses. Finally, while new jobs will be created for installing, operating, and maintaining charging and fueling infrastructure for zero emission MHDVs, the reduced maintenance requirements for these vehicles may result in a loss of jobs in conventional vehicle maintenance and fueling.

Social and Health

As discussed in T2, reducing local criteria air pollutants by eliminating vehicle tailpipe criteria pollutant emissions will reduce health issues associated with these pollutants, especially in communities located near highways or major roadways. As discussed in T2, however, additional electricity generation may increase criteria air pollution in communities near fossil fuel plants, but this risk can be mitigated as fossil fuel electricity generation is phased out and replaced with renewables generation sources.

Also as discussed in T2, electric MHDVs can help stabilize the electric grid by providing a form of electricity storage. This can help balance the grid in times of high electricity demand and reduce curtailment of renewable generation.

Implementation Considerations

Current barriers to zero carbon MHDV adoption include availability of charging infrastructure and fuel supply, high capital costs, and lack of model variety. The following actions could be taken as part of implementing this strategy:

- Especially for battery EV, charging infrastructure that is accessible from highways will need to be established. Chargers will need to be publicly accessible and easy to locate. This involves finding land that can house the chargers. The state could consider incentivizing private landowners to host charging stations or consider state-owned land near highways and roadways.

[17] Catherine Ledna et al., "Decarbonizing Medium- & Heavy-Duty On-Road Vehicles: Zero-Emission Vehicles Cost Analysis," March 7, 2022, https://www.nrel.gov/docs/fy22osti/82081.pdf

- Leverage the environmental and air quality benefits associated with the adoption of the California Advanced Clean Trucks rule under Section 177 of the Clean Air Act.
- Coordinate outreach and education to public and private MHDV fleet managers.
- Promote zero carbon MHDVs in utility actions, such as electric distribution system planning, beneficial rate design and investment in "make-ready" charging infrastructure.
- Plan, construct, and establish management for Hydrogen infrastructure and supply, for effective deployment of hydrogen FCEVs and resulting emissions reduction. Hydrogen supply, ideally of the cleanest and lowest emissions variety, must be readily available across refueling stations.
- Inform consumers of MHDV EV models and provide regular access to charging.
- Encourage companies and agencies with vehicle fleets to apply for Heavy-Duty Emission Reduction Grants (via the IRA) to electrify their fleets and train workers.
- Continue implementation of DEP's Alternative Fuels Incentive Grant (AFIG) Program and Driving PA Forward grant and rebate programs. See the callout box for more information on the Driving PA Forward program.
- Publicize federal tax credits which encourage the manufacture and purchase of clean energy vehicles, and the provision of clean hydrogen or other clean fuel production (such as 45W, 30C, and 45V[18]). To implement this strategy, potential buyers and developers of charging or fueling infrastructure must be able to understand and access tax credits.
  - Natural Gas Hydrogen in AFV refueling and charging property in low-income and non-urban areas are eligible for the 45V tax credit, an important consideration particularly for the equitable deployment of MHD EVs.
  - EPA's Diesel Emissions Reduction Act offers annual grants and rebates to projects which target diesel emissions, in protection of human health and air quality.
- Conduct outreach and education, particularly to small and/or minority-owned businesses to communicate the available tax credits, rebates, and other financial incentives and opportunities related to fleet electrification.
- Lower manufacturing and operation costs for MHDV adoption. This could include vehicle purchase incentives or rebates and incentivizing networked charging.

DEP FUNDING OPPORTUNITIES

Driving PA Forward

The Driving PA Forward grant and rebate programs were developed to improve air quality statewide by driving transformation from older, high-polluting diesel engines to clean transportation technologies.

The goal of the Driving PA Forward Initiative is to substantially and permanently reduce lifetime nitrogen (NOx) emissions from mobile sources of diesel emissions. Of the mobile source NOx emissions, diesel sources, including aviation, marine, and rail sources, account for almost 57% of the mobile source NOx emissions.

[18] "Clean Energy Tax Incentives: Elective Pay Eligible Tax Credits." US Internal Revenue Service. n.d. 5817-G (6-2023). https://www.irs.gov/pub/irs-pdf/p5817g.pdf.

Partners and Participants

Transitioning to zero carbon MHDVs requires immense infrastructural and commercial effort. Companies eligible to electrify their vehicle fleets, landowners proximate to highways who may be able to develop or host fueling stations, and governing bodies to create subsidies and assistance programs for vehicle electrification will be important players. Such key partners include:

- **PennDOT:** Encourage and facilitate transit fleet transitions to clean fuels.
- **Automakers**: Car manufacturers must be able to meet increased demand for zero carbon MHDVs with increased commercial interest and increased grant funding.
- **Electric utilities**: Utilities must be able to supply and handle the charging load requisite for MHD EVs. Utilities may consider and manage networked EV charging to reduce overall loads, where possible.
- **Hydrogen fueling network partners:** As of 2023, there are 59 open retail hydrogen stations, and 50 in development, mostly in California, which are privately run and operated.[19] For a significant deployment of hydrogen FCEVs in Pennsylvania for light, medium, or heavy-duty vehicles, charging and supply infrastructure is a requirement. Companies such as True Zero and Iwatani are hydrogen fueling station operators in California.

Financial Considerations

Depending on the lens from which this strategy is viewed, financial considerations vary.

- For expansion of public charging, consider whether the chargers will be publicly or privately purchased and operated. Pennsylvania could incentivize private buildout of public charging infrastructure.
- Though costs are coming down, EVs have a higher up-front purchase cost, including possible costs to install home or business refueling infrastructure compared to their ICEV equivalent. To overcome this expense, purchasers must realize that savings through anticipated operational fuel, maintenance, and convenience savings over the vehicle's lifetime. Pennsylvania should continue to communicate the available federal tax credits to consumers, and/or implement its own incentives, such as tax credits or tax rebates, to facilitate the transition to EVs.

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[19] "Alternative Fuels Data Center: Hydrogen Fueling Stations." US DOE. n.d. https://afdc.energy.gov/fuels/hydrogen-stations

Participant Lens

- **Voluntary measures:** Participants can choose to voluntarily purchase a zero carbon MHDV. Federal IRA funding provides incentives that can reduce the financial barrier for participants that choose to purchase EVs, and the market cost of electric vehicles has continued to decrease. Though businesses may benefit from decreased fuel costs, they may see electricity bills increase with installation and use of EV charging on their properties.
- **Programmatic:** The state should communicate the available federal tax credits to consumers and/or implement its own incentives, such as tax credits or tax rebates, to facilitate EV adoption. The Low-Carbon Fuel Standard (LCFS), 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, an LCFS-like policy would expand on the ethanol and biodiesel requirements already in place and also include 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.
- **Required from legislation**: The state could require that only ZEV LDVs may be sold in the state after a certain year, following similar policies in California (California Department of General Services - Purchasing Mandate 4121). Such requirements may limit consumer choice.

Implementer Lens

- There may be a mix of public and private ownership, funding, and operation of charging stations. Private implementers will want to seek funding from public sources or from electric utilities.
- Utilities that need to upgrade electrical infrastructure to meet demands of medium and heavy-duty EV charging will seek funding.

Equity & Environmental Justice

Smaller businesses, including family and minority-owned businesses, may face greater strains in electrifying their fleets. Smaller vehicle fleets may purchase MHD EVs from secondary markets, excluding them from incentives for the purchases of new vehicles. Smaller businesses transitioning to clean fleets may also be more strained for workforce development and personnel training on EV operation and maintenance, so it is important that statewide incentives, rebates, or grant funding addresses the transition process after purchasing. Municipalities or PennDOT may also consider offering technical assistance to smaller fleets. This strategy will also mitigate existing air pollution from internal combustion engines and aligns directly with the pollution mitigation priorities of EJ areas, as identified by outreach conducted in the CAEJC program.

Action from the CAEJC Program that aligns with this strategy:

- Mitigate existing sites and sources of air and water pollution.

Industrial Sector

Notoriously hard to decarbonize, the industrial sector includes industry activities such as the processing and manufacturing of physical and chemical materials. Metals manufacturing, chemical products, and food processing are key industries in the Commonwealth.[20] The majority of emissions in this sector result from the combustion of fossil fuels to power processes with other major emissions sources including cement manufacturing, iron and steel production, and the use of ODS substitutes. In 2021, approximately 25% of Pennsylvania's emissions were the result of industrial activities, and the state's industrial emissions have grown by 11% since 2005.

Emissions from industrial processes can be difficult to reduce, especially processes such as cement and concrete production that involve chemical reactions that produce emissions that cannot be avoided without changes to chemical processes. Industries with unavoidable carbon emissions could be coupled with CCUS technologies that capture CO_2 emissions and either utilize or sequester the CO_2 to reduce industrial emissions. Supporting the further development of CCUS technologies is included as a separate strategy in this plan with the goal of applying increasingly mature CCUS technologies in numerous sectors, including industrial.

Due to challenges with unavoidable emissions and due to the fact that the industrial sector is the greatest source of GHG emissions in Pennsylvania, the Commonwealth made reducing industrial emissions a prime focus area of its Climate Pollution Reduction Grant (CPRG) Priority CAP (PCAP).

Strategies

Strategies reflect current technological and policy trends to reduce industrial emissions including improving process efficiency and fuel switching.

Despite the considerable challenges, there are opportunities to have an impact on industrial emissions in Pennsylvania.
Two strategies were modeled in the industrial sector. The first strategy modeled industrial energy efficiency deployed at facilities aiming at reducing electricity and natural gas use through conservation, and investments in plants. In the second strategy, a range of different decarbonization strategies were modeled in existing industrial facilities including opportunities for process changes, fuel switching to gas, and in some cases through electrification. Taken together, modeling results indicate that these strategies will lead to significant emissions reductions in the sector, as shown in Table 13.

Table 13. Industrial sector GHG reduction strategies and associated reductions ($MMTCO_2e$)

GHG Reduction Strategy	2030	2050
I1. Industrial Efficiency[a]	1.67	7.10
I2. Gas, Fuel, and Process Decarbonization[a]	1.43	8.39

[20] "State Energy Profile Data." US EIA. n.d. https://www.eia.gov/state/data.php?sid=PA.

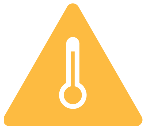
[a] A portion of GHG reduction from this strategy is captured in the electricity generation sector.

For each strategy, the environmental 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 social benefits and costs are expressed in terms of impacts on air quality (e.g., changes in the criteria pollutants like NO_x and $PM_{2.5}$) and associated public health and social impacts such as equity and resilience.

Equity in the Industrial Sector

Accessibility: Accessibility in the industrial sector will primarily focus on the workforce. This entails expanded job opportunities, as well as training and education to advance the strategies set forth in this area.

Advocacy: Numerous EJ areas face disproportionate pollution burdens, including for communities located near existing industrial facilities. Advocating for these communities and ensuring outreach is conducted with them to account for their unique needs will be important in industry efforts to ensure that decarbonization efforts adequately support other vital co-benefits.



Accountability: To support accountability in industrial efforts, transparent reporting of metrics and progress toward decarbonization projects should be regularly reported. Where industries face decarbonization challenges or delays due to technology should also be communicated clearly, especially if goals cannot be met.

I1. Industrial Efficiency

Deploy electricity and gas efficiency in the industrial operations.

KEY METRICS

GHG emissions reductions:

2030: **1.67 MMTCO$_2$e**
2050: **7.10 MMTCO$_2$e**

Cost (or benefit) per ton MTCO$_2$e/reduced): **$415/MTCO$_2$e**

Pennsylvania is home to a range of industrial operations for processing raw materials and finished products with significant diversity. While industrial processes vary significantly across industrial operations (including iron and steel, bulk chemical processes, pulp and paper and other industrial work), nearly all industrial processes have opportunities to enhance their thermal or electrical efficiency. This strategy is supported by national and DEP programs to deploy energy efficiency in industrial facilities throughout the Commonwealth. Programs included in this work include the US DOE's Better Plants Challenge, DEP's E4 (e.g., the Energy Efficiency, Environment, and Economics [E4] Initiative) and implementing the types of actions outlined in DEP's Clean Energy Program Plan.

This strategy leverages a range of incentives and financing for energy efficiency and clean industry solutions available in the Commonwealth, as well as those outlined within the IIJA and IRA. The DOE State Energy Program provides funds for industrial energy assessments and is being expanded with IIJA funds.

Energy efficiency in industrial processes is generally a cost-effective endeavor. However, specific efficiency potential varies significantly across industrial processes.

Resulting Impacts

Environmental

Energy efficiency within industrial emissions 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 NOx, SOx, PM2.5, and VOCs that are ground-level ozone precursors.

Economic

This strategy is expected to have positive economic impacts generally resulting from energy bill savings to industrial uses. However, specific implementation of energy efficiency practices in industrial uses can vary significantly. Particularly because of the scale of energy use in industrial facilities, operational changes and energy conservation practices can provide significant savings for no or low costs. Conversely, larger and more transformative energy efficiency projects in industrial facilities can carry significant costs and may have longer payback periods and/or require financing.

Social and Health

The health impacts of this strategy are provided from the reduction of industrial air pollution from the reduced emissions from generation of electricity and the combustion of natural gas and fuel oil. These processes contribute significant proportions of VOCs, particulate matter (PM2.5 and PM10), and more hazardous air pollutants all of which are linked to increase risk of respiratory and cardiovascular illness, as well as several cancers, diabetes, cognitive impairment, neurological diseases, and adverse impacts during pregnancy.[21] Decreasing pollution from industrial processes will have positive impacts on environmental health disparities like ensuring access to clean water, decreasing risk of respiratory and cardiovascular disease, and protecting the health of vulnerable populations like children, the elderly, and those who are unhoused. Additionally, increasing energy efficiency will have positive impacts such as reduced and lower isolated energy use, leading to improved community resilience in times of need like heat waves or severe storms.

Implementation Considerations

The following actions could be taken as part of implementing this strategy:

- Implement a program that ensures industry reduces energy (electricity, natural gas or fuel oil) consumption through EE&C programs and establishing annual savings targets. This could also be done with a carbon focused program that is fuel agnostic.
- Fund and provide technical assistance to industrial partners through the in-development Reducing Industrial Sector Emissions in Pennsylvania (RISE PA) grant program.
- Streamline permitting processes for industrial decarbonization projects while maintaining proper safety considerations and requiring community consent or engagement as a key part of project approval processes.

RELATED FUNDING OPPORTUNITIES

EPA Climate Pollution Reduction Grant Program

In the Priority Climate Action Plan for Pennsylvania, there will be a priority on the industrial sector. This focus can be used to apply for implementation grants aimed at increasing industrial energy efficiency. Implementation grants can provide between $2 million and $500 million for these projects.

[21] "Health Impacts." World Health Organization (WHO). n.d. https://www.who.int/teams/environment-climate-change-and-health/air-quality-energy-and-health/health-impacts.

- Develop a training incentive program with Labor and Industry (L&I) or through partnerships with state universities and post-secondary institutions to train new clean energy workers to employ energy management systems, conduct scoping audits, and prepare industry to utilize technology to manage and reduce emissions.
- Establish programs, such as clean energy financing (such as the Green Energy Loan Fund [GELF]), facility energy or emissions performance programs or other incentives and mandates to spur action from industry to invest in upgrades to equipment.
  - Industrial facilities have similar opportunities in some cases as commercial buildings (Lighting, HVAC, appliances etc.).
  - Industrial facilities have opportunities that are specific to their processes such as efficiency of compressed air, insulation on high heat equipment or other process support sub-systems that are not in commercial buildings.
  - Federal programs exist that can support this work (for example, the DOE Better Plants Program).

Partners and Participants

Key partners include:

- **Industry and trade groups:** Industry and trade groups may implement electricity and gas efficiency projects, share best practices, and build and disseminate resources for companies and other industrial bodies to become more efficient. Partnering with industry and trade groups enables efficiency planning that is specialized and consequently more effective than sweeping industrial standards.
- **Utilities:** Gas and electric utilities provide crucial support for efficiency programs. While electric utilities in the state of Pennsylvania do not own or operate generation currently, they will play an important role in building and maintaining infrastructure to distribute new generation, maintaining reliability, and advising on potential rate impacts.

Financial Considerations

Depending on the lens from which this strategy is viewed, financial considerations vary.

Participant / Implementer Lens

Project financials may look different than commercial buildings. Some large equipment costs may be heavily specialized, and efficiency may not be priorities for use.

Education of interested parties 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.

- **Voluntary measures:** Regular commissioning of systems may help to maintain efficiency. By verifying that all the elements of a system or facility are designed, installed, tested, operated, and maintained according to the operational requirements.
- **Programmatic:** It is key to ensure that new or repowered lines of industrial processes incorporate EE as much as possible, as these are the best opportunities to instill changes. By designing new processes with energy efficiency as a main consideration, the processes will be more streamlined and cost effective than retrofitting old processes.

Equity & Environmental Justice

Fenceline communities may see benefits from increased efficiency and lower localized air pollution from the same level of production. This can help improve public health outcomes in highly industrialized communities and aligns directly with the air pollution mitigation priorities of EJ areas, as identified by outreach conducted in the CAEJC program. These health outcomes will have a very positive impact for those most vulnerable to air pollution, including but not limited to children, the elderly, those who are unhoused, and those with chronic health conditions like asthma or cardiovascular disease; all of these populations are disproportionately represented in EJ areas.

Action from the CAEJC Program that aligns with this strategy:

- Mitigate existing sites and sources of air and water pollution.

The increased savings on energy bills due to more efficient processes can allow businesses to have more financial flexibility, opening up the potential for more financial investment in the area like community programming for a cleaner environment, employment improvements, public health, and other benefits. It is important to prioritize this for highly industrialized (not going to save them costs, will save air pollution from air quality).

I2. Industrial Gas, Fuel, and Process Decarbonization

***Electrify industrial uses, change industrial processes, and deploy gas and fuel oil alternatives in industrial operations*.**

KEY METRICS

GHG emissions reductions:

2030: **1.43 $MMTCO_2e$**
2050: **8.39 $MMTCO_2e$**

Cost (or benefit) per ton $MTCO_2e$/reduced): **\$179/$MTCO_2e$**

This strategy seeks to decarbonize industrial operations through the electrification of low-temperature processes and by changing industrial processes which generate GHG emissions. Electrification of low-temperature processes are generally easier to employ compared to high-temperature processes, as current technologies are more readily available for lower heat requirements. This is achieved by effectively switching from direct combustion to electricity powered by renewable resources, replacing fossil fuel-based heating systems with electric heating technologies such as heat pumps and radiative heating for processes that require lower temperature ranges. Energy efficiency (Strategy I1) can help support carbon reduction for these industries, which include paper manufacturing, food and beverage production, pharmaceutical production, and textile manufacturing. Those industries that rely on high-temperature operations are not easy candidates for electrification or produce GHG emissions from chemical processes; these include iron, steel, and other metal manufacturing, cement and lime manufacturing, and glass production. Nationally, these areas have been a focus for research and pilot development by federal agencies such as the DOE, and EPA. Though solutions within industrial subsectors vary significantly, many rely on a handful of key methods which would be deployed under this strategy:

- Electrification of low heat operations and processes.
- Changes in chemical processes, production techniques to reduce GHG-emitting by products.
- Using low or no-carbon energy feedstocks as fuel, including Biomethane (Strategy F2) and Hydrogen (Strategy F3) for high heat processes.
- Deploying carbon capture storage technologies (Strategy C1) at the flue sources.

Deployment of crosscutting decarbonization strategies in industrial operations, connected with related fuel supply and carbon capture strategies is envisioned in this strategy.

Resulting Impacts

Environmental

Decarbonization of industrial processes can provide significant environmental benefits. In addition to reductions in carbon pollution, industrial processes also provide significant co-pollutant air pollution including sulfur dioxide, VOCs, and particulate materials, all of which have negative impact to air quality. As a result, this strategy also reduces gaseous and particulate emissions of other criteria pollutants such as benzene and VOCs that can lead to the formation of smog and ozone. In addition, some industrial processes can negatively impact local water quality through point source pollutants. Environmental issues associated with industrial processes are particularly prevalent in older facilities without modern pollutions controls.

Economic

Because of the abundance of natural gas in the Commonwealth and the associated fuel costs, using fossil fuel as an energy and heating source may be comparatively cheap. The switch from natural gas to electricity does not generally result in bill savings for electrification. Cost and economic impacts associated with industrial decarbonization vary significantly as industrial processes themselves and potential decarbonization options vary.

RELATED FUNDING OPPORTUNITIES

CHIPS and Science Act

The CHIPS and Science Act seeks to revitalize the industrial sector through domestic manufacturing, with specific emphasis on clean technologies, thus creates opportunities to grow new businesses such as factories for batteries and other advanced energy equipment that can support the energy transition.

Social and Health

Industrial impacts can have significant impact on health outcomes, particularly for fenceline communities, which are residents who live adjacent to large point source air and water pollution industrial facilities. Fenceline communities, which are disproportionately populated by people of color, are a high risk of negative impacts from air and water pollution exposure, including significant negative health outcomes resulting from their proximity to industrial facilities. Decreasing pollution from industrial processes will have positive impacts on environmental health disparities like ensuring access to clean water, decreasing risk of respiratory and cardiovascular disease, and protecting the health of vulnerable populations like children, the elderly, and those who are unhoused. Additionally, increasing energy efficiency will have positive impacts such as reduced and lower isolated energy use, leading to improved community resilience in times of need like heat waves or severe storms.

Implementation Considerations

The following actions could be taken as part of implementing this strategy:

- Develop a training incentive program with L&I or through partnerships with state universities and post-secondary institutions to train new clean energy workers to employ energy management systems, conduct scoping audits, and prepare industry to utilize technology to manage and reduce emissions.
- Electrify industrial processes and equipment for low- and mid-temperature processes utilizing heat pumps and for high temperature ranges utilizing thermal storage that apply for most heavy industry processes from steel, cement, chemicals, and refining.
- Create analysis to assess rate and tariff design in partnership with the PA PUC to establish, if necessary, affordable industrial user rates that properly values flexible loads while ensuring equitable outcomes (including avoiding cost shifts) for Pennsylvania residents.
- Streamline permitting processes for industrial decarbonization projects while maintaining proper safety considerations and requiring community consent or engagement as a key part of project approval processes.
- Apply for and utilize federal funding where appropriate. There are a range of federal incentives in place to support projects, including funds for technical assistance and capacity building that could help communities navigate a broader range of funding for technical projects.
- Increase funding to leverage PEDA's status as a State Energy Financing Institution (SEFI) recognized by DOE's Loan Programs Office under Title 17 of the Energy Policy Act of 2005, as amended by the IIJA, and leverage DOE Loan Program Office funds to act as a credit backstop for industrial decarbonization projects, similar to the US Department of Agriculture (USDA's) Empowering Rural America program.
- Continue to track research as new, cost-accessible technology is needed for many industrial projects.

Partners and Participants

- **Industry and trade groups:** Will implement projects, share best practices, and provide education on the applications of industrial electrification.
- **State and Federal Government:** Can support new technologies, update regulations, and incentivize investments. They can enable pilot projects by updating regulations or through permitting. This can enable the use of technologies for which a clear regulatory process does not yet exist.

Financial Considerations

Depending on the lens from which this strategy is viewed, financial considerations vary.

Participant and Implementer Lens

There is lots of uncertainty in whether projects will be financially viable and which technologies will be cost effective for this work. This is especially true as technologies vary widely across sectors, and Pennsylvania is home to a diverse range of industries. Implementers and participants will need to assess the changes in cost and stay informed about the development of new, and potentially beneficial, technologies.

Federal funding from the IIJA and IRA can reduce the financial barriers to deploying new technologies.

Action from the CAEJC Program that align with this strategy include:

- **Mitigate existing sites and sources of air and water pollution.**

Equity & Environmental Justice

The equity considerations vary depending on the technologies and specific strategies involved in facilitating industrial decarbonization. During the industrial electrification process, it is key to create inclusive opportunities for all members of the industrial workforce. Reducing the amount of fossil fuels used in industry can result in improved safety and working conditions for industrial employees and an increase in clean energy job opportunities for community members who previously were employed in the fossil fuel sector. Additionally, switching away from combustion and fossil fuel power sources can decrease air pollution, which is in alignment with the air pollution mitigation priorities of EJ areas, as identified by outreach conducted in the CAEJC program.

Fuel and Gas Systems Sector

The fuel and gas systems 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 (60% of net electricity generation as of June 2023),[22] but the supply of biogas and biomethane is growing because coal mines and agriculture, two important sources of biogas and biomethane, are abundant in Pennsylvania.

Pennsylvania produces an abundance of natural gas and is one of the largest natural gas producers in the country. Through its existing facilities, Pennsylvania exports natural gas to other states and regions, and has a broad distribution network. Pennsylvania has the most underground natural gas storage facilities in the United States. Additionally, Pennsylvania is home to a range of petroleum refining facilities and other fuel and system infrastructure.

Strategies

Shown in Table 14, the strategies proposed to address fuel supply emissions reflect current technological and policy trends that aim to reduce methane leaks from current operations and to increase the use of biogas, renewable gas, and hydrogen fuels to reduce methane emissions.

Table 14. Fuel and Gas sector GHG reduction strategies and associated reductions (MMTCO2e)

GHG Reduction Strategy	2030	2050
F1. Operational Efficiency	2.67	7.25
F2. Biomethane	3.46	9.49
F3. Plug Inactive & Marginal Wells	0.00*	4.48

*Implementation for strategy F3. is not expected to begin until 2030; reductions shown in modeling will begin at that time.

For each strategy, the environmental, 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 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.

[22] "Pennsylvania State Profile and Energy Estimates." US EIA. 2023. https://www.eia.gov/state/data.php?sid=PA.

Equity in Fuel & Gas Systems

Accessibility: The strategies for fuel and gas systems are mainly targeted at oil and gas producers but are aimed to maximize air quality benefits.

Advocacy: Particular attention should be placed on how strategies will impact workers and those others who work, live, and go to school in proximity to existing and proposed fuel and gas infrastructure.

Accountability: To remain accountable in this area means understanding the social costs of carbon. Implications of fuel and gas extraction and distribution are more severe in different areas, and therefore solutions should prioritize those areas that have the greatest risk and exposure.

F1. Operational Efficiency

Reduce methane emissions across oil and gas operations.

This strategy aims to reduce methane emissions from high-production upstream and midstream oil and gas operations. The strategy builds upon recently proposed rules from the US EPA and looks to ongoing research to guide future actions. A small number of very large sources are responsible for a significant fraction of emissions from unconventional oil and gas production systems.[23,24] Emissions could be reduced significantly if these very large sources were: 1) detected and repaired as soon as possible or 2) prevented from occurring.

The proposed strategy to reduce these emissions is twofold. First, following the lead of the US EPA,[25] it recommends an increased frequency for the detection and repair of leaks, importantly requiring more frequent testing for large leaks and enabling innovation in methods employed for leak detection (e.g. less accurate but more widely deployable methods can be used to detect large leaks with a higher frequency). Methane leak mitigation actions vary, but common technologies include the installation of vapor recovery units, routing blowdown gas to flare, replacement of reciprocating rod-packing systems, in addition to implementing leak detection and repair programs. Second, the strategy aims to support ongoing research into the primary causes of these large leaks and aims to use key findings to continually update best practices. As this research is published, appropriate best management practices will be recommended to prevent these large leaks from occurring in the first place.

KEY METRICS

GHG emissions:

2030: **2.67 $MMTCO_2e$**

2050: **7.25 $MMTCO_2e$**

Cost (or benefit) per ton $MTCO_2e$/reduced): **\$12/$MTCO_2e$**

Resulting Impacts

Environmental

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. With a higher global warming potential than

[23] Cusworth, Daniel H., Andrew K. Thorpe, Alana K. Ayasse, David Stepp, Joseph Heckler, Gregory P. Asner, Charles E. Miller, et al. 2022. "Strong Methane Point Sources Contribute a Disproportionate Fraction of Total Emissions across Multiple Basins in the United States." Proceedings of the National Academy of Sciences 119 (38): e2202338119. https://doi.org/10.1073/pnas.2202338119.
[24] Caulton, Dana R., Jessica M. Lu, Haley M. Lane, Bernhard Buchholz, Jeffrey P. Fitts, Levi M. Golston, Xuehui Guo, et al. 2019. "Importance of Superemitter Natural Gas Well Pads in the Marcellus Shale." Environmental Science & Technology 53 (9): 4747–54. https://doi.org/10.1021/acs.est.8b06965.
[25] OAR US EPA. "EPA Issues Supplemental Proposal to Reduce Methane and Other Harmful Pollution from Oil and Natural Gas Operations." Other Policies and Guidance. October 11, 2022. https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-operations/epa-issues-supplemental-proposal-reduce.

CO_2,[26] methane is a potent GHG, and reducing its emissions yields significant environmental benefits, helping to limit near-term climate change. This strategy is also expected to reduce gaseous emissions of air toxins and ozone precursors such as benzene and VOCs.

Economic

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 technologies utilized, the amount of gas captured, and the time required to recoup those investments through the sale of additional captured gas. A small number of large leaks account for a large fraction of methane emissions from unconventional oil and gas production.[27] As a result, prevention and rapid repair of these large leaks is cost effective for the emissions reductions that result.

Increased emphasis on leak detection and prevention will hopefully lead to innovation and growth in such technologies and their sale and could potentially induce jobs in these fields.

Social and Health

Methane reduction strategies improve air quality by reducing and capturing GHG pollutants before being released to the atmosphere. In addition to climate benefits, these mitigative actions promote safety at operating facilities by reducing leakage of 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. Methane leak mitigation will also lead to improved health outcomes for residents near to operations, who have often historically been harmed by EJ issues.

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[26] OAR US EPA. "Understanding Global Warming Potentials." Overviews and Factsheets. January 12, 2016. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.

[27] Brandt, Adam R., Garvin A. Heath, and Daniel Cooley. 2016. "Methane Leaks from Natural Gas Systems Follow Extreme Distributions." Environmental Science & Technology 50 (22): 12512–20. https://doi.org/10.1021/acs.est.6b04303.

Implementation Considerations

Implementation of the strategy would likely take place in two phases. The first phase would implement the proposed EPA Methane Rule. An enhanced leak detection and repair program will be required for all producers in the state of Pennsylvania. This enhanced leak detection and repair program would include the following enhancements to current regulations:

- Higher-frequency leak detection for high-producing and complex production sites.
- Flexibility in leak detection technology including higher detection thresholds for potentially large emitters.
- Annual leak detection and repair requirements for all producing sites.

DEP has worked with carbon mapper and the US Climate Alliance to conduct flights with methane detection technology in order to identify sources of leaks. Methane emission reductions through increased controls and leak detection are also supported through the implementation of the EPA's final new source performance standards and proposed EPA rule to reduce methane as a part of the IRA. Pennsylvania can build on the success of this Carbon Mapper collaboration to quickly alert operators of large methane emission events and inform mitigation efforts.

The intent of more frequent leak detection and repair for high-producing and complex production sites is to capture large leaks more rapidly. Enabling flexibility in the technology will enable more cost-effective, higher-frequency leak detection technology to be deployed, capable of detecting the large leaks responsible for a majority of methane emissions but potentially costing less to implement and moving toward continuous leak detection methods. Annual leak detection and repair for all producing sites is intended to remove the long-tail of relatively large emissions that can occur even with marginal wells.

The second phase of implementation relies on ongoing research. The US DOE and others are supporting research that is likely, within the time frame of a few years, to provide new clarity on the causes of the large emissions that periodically take place at oil and gas production facilities. These findings will guide best management practices to prevent leaks from occurring. Recommended implementation steps, therefore, are:

- Periodic review of emerging research concerning the causes of large methane emissions at oil and gas production facilities; and
- Implementation of best management practices to prevent large leaks as research reveals the cause(s) of these leaks.

Partners and Participants

Partners and participants needed to implement the first strategy include:

- **Oil and Gas Producers**: The producers would be required to implement and operate this leak detection and repair technologies.

- **Oil and Gas Technology Companies**: Substantial research and innovation is currently underway to produce more effective and efficient leak detection technologies. These technologies, as they are developed and enter the marketplace, will ideally reduce the cost and improve the effectiveness of leak detection and repair efforts.
- **State regulators**: The state would be asked to oversee the implementation of new leak detection and repair requirements. The state would also be asked to review and approve emerging leak detection and repair technologies as they are brought to the marketplace.

Partners and participants needed to implement the second strategy include:

- **Scientists and engineers**: Research is required to determine the causes of large leaks in oil and gas production operations. As noted, this research, largely funded by the federal government and including the participation of the oil and gas industry, is underway.
- **State regulators**: The state would be asked to evaluate ongoing research results and, as a clear path forward to prevent large leaks emerges, implement best management practices in-state rulemaking.
- **Oil and Gas Producers**: The producers would be required to implement these best management practices.

Financial

The financial considerations of this strategy vary depending on the lens from which they are analyzed.

Participant Lens

- **Voluntary measures:** Oil and gas producers could voluntarily implement technological changes that will in part be offset by increased capture of methane in production activities. These technological changes to both detect and plug leaks will have costs associated with purchase, installation, and replacement of existing equipment. Costs for these technologies could be offset over time by the additional generated from the sale of gas that would previously have been lost to leaks. Technology companies will also likely invest in the development of new leak detection technologies with the goal of offsetting these costs with revenues from the sales of their products.
- **Required from legislation:** Meeting any new leak detection and plugging requirements will have costs associated with monitoring and compliance in addition to costs associated with technological changes and/or leak plugging activities.

Implementer Lens

The state will require funding to implement and enforce new regulations. Costs associated with additional staff and staff training may be required.

Equity & Environmental Justice

Increasing compliance requirements to reduce uncaptured methane emissions was a priority action identified by the CAEJC program that directly aligns with this CAP strategy. To help ensure equitable implementation of this strategy, the costs of emissions reductions should be borne by those who benefit the most from the production and consumption of oil and gas products, and not distributed across society in a way that is unrelated to the consumption and production of oil and gas.

Health impacts of leakage of VOCs and other possible air toxics from oil and gas production operations have the greatest impact on people living in close proximity to production facilities. These populations suffer environmental damages that are inequitable as they often do not benefit in any direct way from the oil and gas production close to their homes or businesses. Minimizing leakage of methane from these facilities will also minimize the leakage of VOCs that are a portion of natural gas. Thus, reduced methane leakage from oil and gas production improves environmental equity by minimizing health damages to people living close to production facilities. As a result, this strategy supports air pollution reduction which was also identified as a priority area by CAEJC outreach.

Actions from the CAEJC Program that align with this strategy include:

- **Increase compliance requirements to reduce uncaptured methane emissions.**
- **Mitigate existing sites and sources of air and water pollution.**

F2. Biomethane

Expand use and generation of Biomethane fuels.

This strategy aims to increase the production and use of biomethane from sources including animal manure, food waste, landfill gas, water resources recovery facilities, agricultural residue, energy crops, forestry residue, and municipal solid waste, in some cases capturing GHGs that would be emitted into the atmosphere and using them to replace traditional natural gas and reducing net emissions. Biomethane development from animal waste also has the dual benefit of increased nutrient management and can lead to positive impacts on odor and can improve nutrient efficiencies.

This strategy considers the potential for biomethane with specific applications in Pennsylvania and regionally for several feedstocks identified in the American Gas Foundation Renewable Natural Gas report. While some biomethane will be used in onsite applications, a majority could be incorporated into the overall gas supply in pipelines to reduce the per unit emissions of the natural gas supply in Pennsylvania, particularly for those use cases that are difficult to electrify.

KEY METRICS

GHG emissions reductions:

2030: **3.46 $MMTCO_2e$**
2050: **9.49 $MMTCO_2e$**

Cost (or benefit) per ton $MTCO_2e$/reduced): **\$301/$MTCO_2e$**

Resulting Impacts

Environmental

The emissions associated with the combustion of biomethane, while similar in composition to those from geologic natural gas, are considered biogenic carbon emissions. As described in the callout box, biogenic CO_2 emissions can be considered a net zero source of emissions. Displacing fossil natural gas with biomethane will lead to a decline in net emissions of GHGs.

Economic

Increasing the production of biomethane is expected to have overall positive economic impacts. Investments in the biomethane sector are expected to spur job growth from the creation of capture systems to the interconnection of biomethane production locations into existing natural gas pipelines and infrastructure. The driver of negative economic impact from this strategy stems from the reduction in traditional natural gas production, although biomethane is not expected to have the capacity to fully supplant natural gas use at current levels. Biomethane is also currently more expensive than fossil natural gas, resulting in increased energy costs. Investment in scaling up production of biomethane can help close that cost gap.

Social and Health

Biomethane production offers the benefit of reducing waste by incorporating waste products (e.g., agricultural residue and municipal solid waste) as feedstocks for the production of biomethane. This can divert waste from landfills, capture biogas that is currently being flared from landfills, wastewater treatment facilities or other facilities, and help generate useful energy that can be used locally or provided to the grid. Through decentralization of the sources of natural gas, this strategy will increase the resilience of Pennsylvania's energy supply, allowing Pennsylvania to have alternative sources of gas production if fossil natural gas production is disrupted.

When combusted, biomethane releases VOC's, $PM_{2.5}$, and CO, which are contributors to community Air pollution. Use of biomethane instead of natural gas for combustion indoors, contributes to indoor air pollution. Due to the combustion of biogenic carbon, the carbon dioxide emissions are considered to be net zero. See the callout box on Biogenic vs Fossil Emissions.

Because biomethane is more expensive than fossil natural gas currently, shifting to biomethane without also increasing gas efficiency can lead to higher energy costs and greater energy burden on communities. Special attention and policies should be made to ensure that the emissions reductions are not outweighed by the costs of continuing air pollution and increased energy burden when developing a strategy of increasing biomethane supply.

Implementation Considerations

The following actions could be taken as a part of implementing this strategy:

- To develop and scale biomethane production throughout the Commonwealth,
- Support education on biomethane, how it is generated, and its uses, including work with local governments to develop feedstocks from government owned wastewater and landfill facilities.
- Development of a renewable gas standard or carbon emissions standard (based on either lifecycle or combustion of emission) whereby a certain amount of gas used by facilities would need to come from biomethane, or low-carbon fuels.

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 balance in the atmosphere. When a biogenic fuel like biomethane is combusted, the biogenic carbon (which operates in the natural carbon cycle at earth's surface and atmosphere) that was absorbed by the organic matter the biomethane was made from is returned to the atmosphere, creating net-zero carbon dioxide emissions from combustion. Trace amounts of non-CO_2 GHGs are emitted from the combustion of biomethane, however since the impact is very small, this study calculates biomethane emissions using a zero GHG emissions approach for the fuel.

Partners and Participants

- **Companies and farms running feedstock operations:** Suppliers of biomethane feedstocks, including farms, waste management facilities and land management entities would need to work to develop projects to store and transport feedstocks.
- **Gas distribution and supply companies:** Gas utilities play a crucial role in procuring and using biomethane as well as educating customers on the product and potentially exploring programs or rates to implement biomethane use.
- **Industrial, commercial fleets, utilities, and other commercial gas users**: Large users can offtake biomethane to reduce emissions from their buildings, vehicles, or industrial operations.
- **State and Local regulators**: Regulators locally, at DEP and with the PUC may have a role in the oversight of permitting of new biomethane production facilities as well as integrating biomethane into the gas systems with utilities. If a renewable gas portfolio standard was set in place, DEP would work with legislators to set targets and track biomethane use by Pennsylvania's natural gas utilities and the PUC would work to establish mechanisms by which the utilities could recover their investments in projects.

Financial Considerations

The financial considerations of this strategy vary based upon the lens from which they are viewed.

Participant Lens

Feedstock providers, including farms, waste management facilities and land management entities will incur capital costs to develop projects, whose cost may be covered in collaboration with project developers. These providers could anticipate a new revenue stream by selling their feedstock or developing projects. Industrial and commercial gas users could opt for higher gas costs from biomethane to reduce GHG emissions from their facilities.

Implementer Lens

Regulators may see increased activity to permit facilities and DEP and PUC may need additional resources to manage a new renewable gas portfolio standard or to review gas utility investment recovery.

Equity & Environmental Justice

Biomethane was not discussed by the CAEJC, however there are a number of related equity concerns. New biomethane projects may result in the creation of job opportunities, and new revenue streams for specific small businesses such as farms and local communities. Organizations and individuals can benefit from jobs that arise from these programs. There are considerable equity considerations, especially given the higher cost of biomethane at present which could carry through to energy rates. Equitable implementation should include consideration of the financial implications for low-wealth communities, including the potential need to provide bill assistance or opt residents out of procurement of biomethane should biomethane raise energy rates. Additionally, biomethane production plants, like other industrial facilities, have the potential to impact EJ areas which are already disproportionately sited for industrial production facilities despite community resistance. Any negative impacts associated with the construction and operation of biomethane production plants must be accounted for so as to not adversely impact communities facing EJ issues. The Interim Final EJ Policy could be leveraged as a policy tool to establish guidelines and monitoring methods to mitigate these impacts.

F3. Plug Inactive and Marginal Wells

Reduce methane emissions from inactive oil and gas wells.

Nearly half of Pennsylvania's methane emissions from oil and gas operations stem from marginal wells that account for less than 1% of statewide oil and gas production.[28,29] A marginal well, as defined by the Internal Revenue Services (IRS), produces less than 15 barrels of oil or equivalent, or less than 90,000 cubic feet (90 MCF) of natural gas per day.[30] This strategy encourages producers to plug inactive and marginal conventional wells, significantly reducing statewide emissions while having nearly no appreciable impact on energy production. One approach would rely on the strategy followed in the EPA Methane Rule that is currently under consideration. This Rule requires leak detection at all oil and gas wells if they are still producing. Once plugged, monitoring at a well can be stopped. This leak detection requirement, in addition to ensuring that leaks are identified and repaired, encourages the plugging of truly marginal wells. Additional incentives could be phased in over time to increase the motivation to plug these wells that contribute a large fraction of emissions but a very small fraction of production.

KEY METRICS

GHG emissions reductions:

2030: **0 MMTCO$_2$e**
2050: **4.48 MMTCO$_2$e**

Cost (or benefit) per ton MTCO$_2$e/reduced): **\$134/MTCO$_2$e**

This work can be merged, to some extent, with efforts to plug abandoned wells. Emissions from abandoned wells are much smaller, and the cost of plugging them is often much higher (since the sites are often unknown and remote). Motivation for plugging abandoned wells is more taken from health and safety considerations than as a cost-effective means of reducing methane emissions. Plugging marginal wells will also prevent the creation of new abandoned wells.

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[28] Mark Omara, Melissa R. Sullivan, Xiang Li, R. Subramanian, Allen L. Robinson, and Albert A. Presto, 2016. "Methane Emissions from Conventional and Unconventional Natural Gas Production Sites in the Marcellus Shale Basin." ACS Publications. https://pubs.acs.org/doi/full/10.1021/acs.est.5b05503.
[29] Mark Omara et al. "Methane Emissions from US Low Production Oil and Natural Gas Well Sites." *Nature Communications* 13, no. 1 (April 19, 2022): 2085. https://www.nature.com/articles/s41467-022-29709-3.
[30] Amy Townsend-Small. "Measurements from marginally producing oil and gas wells indicate they are a disproportionate source of methane relative to production." University of Cincinnati. 2021. https://www.epa.gov/system/files/documents/2021-12/10_epa-ghgi-townsend-small-nov-2021.pdf.

Resulting Impacts

Environmental

Methane emissions are expected to decrease as a result of this strategy, yielding significant environmental benefits and helping to limit near-term climate change. This strategy is also expected to reduce gaseous emissions of air toxics and ozone precursors such as benzene and VOCs.

Economic

Plugging wells can be costly. The locations of abandoned wells are not all known, though the locations of marginal wells are generally known in Pennsylvania. As a result, reducing emissions from marginal wells should be easier, result in greater emissions reduction, and cost less than plugging abandoned wells, as no searching is required to identify the well. Cost/benefit regarding reduction of methane emissions strongly favors focusing on marginal wells over abandoned wells.

Social and Health

Abandoned oil and gas wells can pose a significant risk to public health through groundwater contamination and the risk of explosions. This strategy may limit the creation of new abandoned wells, thereby improving public health by reducing emissions and other well hazards.

Implementation Considerations

Implementing this strategy should focus on encouraging more frequent leak detection and repair at oil and gas producing wells, in alignment with Strategy F1. To help achieve this, the state could adopt similar requirements as those found in the EPA's new Methane Rule, which requires annual leak detection and repair at all producing oil and gas wells. The state's implementation plan for this rule will be submitted March 2026. These added detection costs will likely encourage producers to close wells that are marginal and are not producing enough to offset costs. Alternatively, or in conjunction with such requirements, new financial incentives could be explored and implemented for oil and gas producers to plug marginal wells.

RELATED FUNDING

Methane Emissions Reduction Program

Supported through the IRA and new authorities under Section 136 of the CAA, the Methane Emissions Reduction Program will help reduce GHG and non-GHG (VOCs, hazardous air pollutants) emissions from the oil and gas sector through more than $1 billion in financial and technical assistance. The Methane Emissions Reduction Program also establishes a charge on wasteful methane emissions and requires EPA to revises the Greenhouse Gas Reporting Program (GHGRP) regulation for subpart W, which covers the oil and gas sector.

Partners and Participants

- **Oil and Gas Producers**: The producers would be required to implement and operate the leak detection and repair technologies associated at all production sites. This requirement would yield a financial incentive to plug marginal wells. Producers should also be consulted regarding effective incentives for plugging additional marginal wells.
- **State regulators**: The state would be asked to oversee the implementation of new leak detection and repair requirements. The state would be asked to envision, review, and implement one or more new incentives or rules encouraging the plugging of marginal wells.

Financial Considerations

The financial considerations of this strategy vary based upon the lens from which they are viewed.

Participant Lens

Oil and gas producers will incur costs for leak detection and repair, and ultimately, for closing marginal wells. They may seek to explore alternative revenue streams or could explore converting closed well lands to renewable energy generation facilities.

Implementer Lens

Regulation enforcement costs to enforce established leak detection and repair requirements. Such costs could include labor for inspectors and other regulatory and enforcement personnel.

Equity & Environmental Justice

Increasing compliance requirements to reduce uncaptured methane emissions was a priority action identified by the CAEJC program that directly aligns with the implementation of this CAP strategy. Additionally, this strategy supports the capping of orphaned and abandoned wells which was also identified as a priority area by CAEJC outreach. To support equitable implementation of this strategy, the costs of emissions reductions should be borne by those who benefit the most from the production and consumption of oil and gas products, and not distributed across society in a way that is unrelated to the consumption and production of oil and gas.

Health impacts of leakage of VOCs and other possible air toxics from oil and gas production operations have the greatest impact on people living near inactive production facilities. These populations suffer

Actions from the CAEJC Program that align with this strategy include:

- Increase compliance requirements to reduce uncaptured methane emissions.
- Locate and cap/cover orphaned and abandoned methane wells.
- Mitigate existing sites and sources of air and water pollution.

environmental damages that are inequitable as orphaned wells are often concentrated close to EJ areas where economic considerations like lower housing price may adversely incentivize Pennsylvanians to move into or remain in these areas, unaware of the potentially adverse health impacts. Minimizing leakage of methane from these inactive facilities will also minimize the leakage of VOCs that are a portion of natural gas. Thus, reduced methane leakage from oil and gas production improves environmental equity by minimizing health damages to people living close to inactive production facilities.

Power Generation Sector

The electric energy system consists of three sub-systems: generation, transmission, and distribution. The majority of the generation system consists of large power plants with several hundred megawatts of capacity that generate power. The energy generated by these power plants is routed to substations where it is then stepped up in voltage and transmitted via high-voltage transmission lines that typically run overhead and are supported by towers. Transmission lines also serve to transmit power within power systems and are not always associated with power plants. Transmission systems are highly interconnected to provide redundancy and continued reliable service in the event of the loss of a line. Along the transmission route, substations serve as routing and switching points to direct power as needed. When energy generated by central station power plants reaches load centers, power is routed again through substations where the voltage is stepped down to distribution levels. Distribution feeders route the power throughout cities and towns where it can be used directly at distribution voltage levels by larger customers or where the voltage is stepped down further for use by commercial and residential customers.

Electricity generation accounts for nearly 30% of Pennsylvania's total emissions, with emissions from this sector primarily caused by burning fossil fuels such as natural gas and coal. Pennsylvania is the second-largest energy producing state in the United States after Texas and is both the third largest coal-producing state and the second-largest natural gas-producing state.[31] Pennsylvania is also second in electricity generation from nuclear power, which currently accounts for about a third of utility-scale electricity generation in the state.[32] Natural gas is the predominant fossil fuel for generating electricity in Pennsylvania, accounting for over 60% of generation.

The transition from coal to natural gas and, to a lesser degree, the gradual increase in renewable energy sources, has reduced overall emissions from the sector significantly since 2005. Decreasing costs of renewable energy technology and enabling policies such as AEPS have helped drive recent increases in renewable power generation. Since 2010, grid-scale wind and solar capacity in the state has doubled to over 1,600 MW, providing about 2% of total electricity generation in 2022.[33]

Strategies

The electric system is changing as greater amounts of grid-scale renewable generating capacity are added and as greater amounts of smaller, distributed generating units are added closer to load centers (e.g., rooftop solar). Strategies P1 and P2 aim to leverage ongoing trends driving grid decarbonization while maintaining grid reliability and increasing grid modernization and resilience.

These strategies, shown in Table 15, are critical to address in concert, as the shifting grid resource mix and increase in distributed resources will require grid upgrades.

[31] "Pennsylvania State Profile and Energy Estimates." US EIA. 2023. https://www.eia.gov/state/data.php?sid=PA.
[32] "Pennsylvania State Profile and Energy Estimates." US EIA. 2021.

[33] "Historical State Data." US EIA. 2022. https://www.eia.gov/electricity/data/state/.

For example, as the grid becomes more decentralized with smaller generation plants (e.g., rooftop solar, Strategy B5), investments in both core grid infrastructure such as lines and substations, as well as in software systems will be required. The current electric grid was designed for "one-way" flow with energy flowing from central station generation plants outward to customers. A more decentralized grid will require two-way flow and investments to strengthen the "grid edge" to allow distributed generators to inject power near the edges of the grid. There will also be a need for grid modernization investments such as switches, sensors, and controls to improve grid operator's visibility into the output of those distributed resources and enhance grid flexibility.

Benefits Quantification

Note that for P1, P2, B2, and B5 GHG reductions were modeled and reported collectively. This modeling indicates how the full potential GHG reduction achieved by each strategy is co-dependent on the successful implementation of all of these strategies. Additionally, for P1, P2, B2, B4, and B5, the cost (or benefit) per ton $MTCO_2e$/reduced were modeled and reported collectively because these strategies have significant overlap of their implementation costs and benefits.

Another aspect of reaching the state's GHG goals will rely on electrification of end-use sectors, namely transportation (Strategies T2, T3) and buildings (Strategy B4), which will lead to increased demand for electricity. For example, as the number of EV increases, so will the peak electric demand on the grid. This increased demand will require investments in core grid infrastructure to reinforce the grid to meet this increased demand while still providing reliable service. Similar to distributed solar, investments in software systems will be needed to help effectively manage the charging of all these new vehicles to minimize peak demands and their impact on the grid.

Table 15. Power Generation sector GHG reduction strategies and associated reductions ($MTCO_2e$)

GHG Reduction Strategy	2030	2050
P1. Net Zero Grid	10.91	39.42
P2. Distribution & Transmission Lines	N/A	N/A

For each strategy, the environmental 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 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.

Equity in the Power Generation Sector

Accessibility: The upfront costs of renewable energy deployment and of supporting grid improvements can be expensive. With current ratepayer structures, it will be important to ensure that affordability is maximized for program participants and that EJ areas have access to renewable energy, even if not onsite, through options such as PPAs. Additionally, prioritizing EJ participation in the new clean energy workforce through intentional programming could help maximize the employment co-benefits of the power generation strategies in this CAP. This could involve workforce training for existing fossil fuel workers in need of retraining to fulfill workforce needs for an evolving clean power sector.

Advocacy: To prioritize the wellbeing of all constituents in efforts addressing power generation, DEP should continue to communicate and engage with communities facing EJ issues to advocate for climate actions of most interest to the community.

Accountability: To ensure accountability, it will be important to identify intended outcomes and benefits, monitor actions that have been implemented in the power generation sector, review impacts and progress on commitments, share updates with interested parties in the community, and incorporate feedback following a dynamic and predetermined cadence.

P1. Net Zero Grid

Build a net zero carbon electricity grid.

This strategy is aimed at leveraging clean and renewable resources in the region to achieve a net zero electricity generation sector in the state. Pennsylvania has already seen significant reductions in emissions from electricity generation, with carbon dioxide emissions declining 38% from 1990 to 2021[34], largely due to a shift from coal fired to natural gas-fired electricity generation. While grid-scale renewable capacity has also increased in recent years, the state has a long way to go to reach a reliable and clean electricity generating portfolio.

To support realization of a net zero grid, the state will need to consider policy changes to regulate carbon emissions in the state or require an increasing share of electricity sales to come from clean energy resources within the state and surrounding region. This strategy assumes realization of a net zero electricity grid by 2050, which could be met through a combination of resources including existing nuclear, new small modular reactor nuclear, solar, wind, hydroelectric power, storage, biomass, coal- or gas-fired power plants with carbon capture technology or gas-fired power plants utilizing low-carbon fuels such as biomethane or hydrogen. For these technologies to be deployed at the pace and scale needed, the state will need to consider permitting reform to ensure new clean energy projects can be sited and developed within the state in a timely manner.

This strategy will be able to leverage federal funding from the IRA, which expanded tax credits for clean technologies, including wind, solar, nuclear (new and existing), carbon capture, battery storage, and low-carbon fuels, all of which are critical to reaching a net zero power sector in the state. The state may consider additional incentives for existing nuclear facilities to ensure the units do not retire before they reach their 60- or 80-year lifetimes. Additionally, while the IRA offers significant incentives for many clean electricity generating technologies, emerging technologies such as CCS and long-duration storage will still need support during early-stage adoption before they reach maturity.

KEY METRICS

GHG emissions reductions:

2030: **10.91 $MMTCO_2e$**
2050: **39.42 $MMTCO_2e$**

Cost (or benefit) per ton $MTCO_2e$/reduced): **$60/$MTCO_2e$**

[34] "Historical State Data." US EIA. n.d. https://www.eia.gov/electricity/data/state/index.php.

Resulting Impacts

Environmental

Decarbonizing electricity generation reduces emissions of CO_2 and other GHGs, such as CH_4 and N_2O, associated with the unabated combustion of fossil fuels. In addition to GHGs, reducing the volume of fossil fuel combustion also reduces criteria pollutant emissions such as NO_x, SO_x, $PM_{2.5}$, and VOCs that are ground-level ozone precursors.

Economic

The creation of a net zero 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, and the financial incentives in the IRA will mitigate a portion of the costs to build new electricity generating resources, reducing the burden on ratepayers. Some manufacturing and utility jobs will also result from the construction and will be maintained over the long-term for operation and maintenance. However, the fossil fuel industry will be negatively impacted, as shifting away from coal and natural gas will result in job losses. Some fossil fuel power plants may remain operating with an investment to add carbon capture technology or by switching to low-carbon fuels.

Social and Health

Decarbonizing the power sector improves air quality and also provides a benefit to public health by reducing gaseous and particulate emissions associated with fossil electricity sources, including criteria pollutants such as NO_x, SO_x, $PM_{2.5}$, and VOCs. These reductions are seen in all types of communities, both in and out of Pennsylvania.

As mentioned above, shifts in the traditional fossil fuel job market could also have adverse social impacts as Pennsylvanians rely on oil and gas production not only for industry jobs, but also for the support of local businesses and other institutions. Closure of production facilities could mean the closure and replacement of energy business types within communities, such as from natural gas to biogenic gas, to other land-based renewable energy opportunities (e.g., geothermal, energy storage, etc.).

RELATED FUNDING OPPORTUNITIES

Investment Tax Credit Expansion

The Investment Tax Credit (ITC) allows for a reduction in tax liability based on a percentage of the eligible investment costs. This credit was extended to facilities installing energy and electrical equipment starting construction before 2025. Base incentives are dependent on the size of the project and adherence to prevailing wage and apprenticeship requirements. There are additional bonuses to these credits if the project is in an energy community and if domestic manufacturing requirements are met.

Implementation Considerations

The following actions could be taken as part of implementing this strategy:

- Change the AEPS to increase the share of renewable and/or low-carbon energy supplying the grid.
- Further regulation or market-based solutions to reducing carbon emissions from existing and new electricity generating sources.
- Communicate and promote federal and state funding opportunities for localities, households, and businesses transitioning to clean energy sources.
- Streamline and modify siting, permitting, and interconnection processes to make widespread and rapid deployment of clean energy projects possible.
- Establish educational and training programs to bolster the state's clean energy workforce to support the installation and maintenance of clean energy technologies.
- Support the development of energy storage facilities to bolster grid reliability with an increasing penetration of intermittent renewable resources such as wind and solar.
- Maintain existing nuclear facilities and develop new small modular nuclear power.
- Facilitate the responsible closure of high-emission coal fired power plants as supplemented by the installation of new clean energy sources.
- Monitor grid reliability as the grid shifts to lower-carbon resources. With greater reliance on electricity, it will be critical to ensure that renewable energy sources with inconsistent power (e.g., solar and wind) are connected to substantial networks of power storage and potential backups in the case of outages or periods of low power provision (e.g., sun or wind exposure).

Partners and Participants

Key partners include:

- **Electric Utilities and PA PUC:** Close coordination with utilities and the PA PUC will be crucial to transitioning the current grid to lower-emission alternatives while providing reliable power coverage, responsibly managing retired infrastructure, and managing rate structures and impacts. While electric utilities in the state of Pennsylvania do not own or operate generation currently, they will play an important role in building and maintaining infrastructure to distribute new generation, maintaining reliability, and advising on potential rate impacts.

- **Regional organizations including the Federal Energy Regulatory Commission (FERC) and PJM:** FERC is responsible for approving or denying new transmission infrastructure projects and works with the Regional Transmission Organizations (e.g., PJM) to regulate wholesale electricity markets. PJM is the Regional Transmission Organizations (RTO) that oversees the electricity wholesale marketplace in Pennsylvania and the neighboring region. The state will need to coordinate with FERC and PJM to facilitate interconnection queue reforms to reduce delays and to coordinate transmission investments in the region.
- **Independent Power Producers (IPP):** IPPs will need to be included in coordination on efforts to decarbonize the power grid on determining where and what type of generation is built, in addition to similar actions as mentioned for electric utilities and PA PUC.
- **Local community and advocacy groups:** Establishing a working relationship with local community and advocacy groups will help with permitting, zoning and other local issues associated with the deployment of net zero emissions electricity facilities and identify opportunities for beneficial implementation and siting of infrastructure.
- **Community and Technical colleges:** Workforce development will require partnerships with educational institutions to ensure that Pennsylvania has an adequate workforce to deploy clean energy technologies efficiently and effectively.
- **Municipalities:** Responsible for local zoning regulations, municipalities can support more streamlined siting and permitting processes for renewable energy in their jurisdictions.

Financial Considerations

Depending on the lens from which this strategy is viewed, financial considerations vary.

Participant Lens

To support clean energy projects, ratepayers pay for increased alternative energy through a state-run program (in Pennsylvania through the AEPS) through which can slightly increase utility bills. However, the cost of renewable energy sources (specifically of wind and solar energy) is decreasing and projected to stay lower than those of new fossil fuel sources. This comparatively lower cost of energy may offset the initial investments in renewable energy projects for rate payers. Additionally, infrastructure investments to improve the transmission and distribution systems, however, may make up an increasing portion of retail rates, regardless of how cost-effective the energy generating technology becomes.

Implementer Lens

Administrators may need to seek additional funding from the federal government to support the development of clean energy projects.

The state will require funding to implement and enforce any new power sector regulations or permitting reforms. Costs associated with additional staff and staff training may be required.

Administrators may also need to seek additional funding from the federal government to support the development of incentive programs to support the deployment of reliable clean energy resources, especially support for the piloting of emerging technologies, such as CCS, hydrogen, or long-duration storage.

Equity & Environmental Justice

The state will need to ensure that equity concerns are addressed during the siting process and that the economic benefits of the increased clean energy development will directly benefit EJ areas. Decarbonizing the power grid will improve air quality and reduce the strain on public health from fossil fuel electricity sources. By reducing air and water pollution from fossil electricity sources and by supporting solar energy sources, this strategy aligns with CAEJC priority actions.

Precedent exists for developing renewable or alternative energy projects on the brownfield sites that remain in the place of decommissioned coal plants. Doing so can increase nearby home property values and maintain the tax base of the area. This helps ensure that communities are equipped to provide public service. Repurposing plants can also streamline the permitting process for siting renewable or alternative energy projects, which increases the administrative feasibility of adding clean energy projects to the power mix.

Decarbonizing power generation provides opportunities for job creation. The Commonwealth can prioritize local and historically disadvantaged communities as the beneficiaries of employment opportunities in clean energy industries. Several counties in Pennsylvania were awarded funding to support displaced workers from the coal industry, including Bedford, Cambria, Somerset, Allegheny, Erie, Greene, Lycoming, and Westmoreland counties.

Actions from the CAEJC Program that align with this strategy include:

- Support physical and policy infrastructure for solar energy sources at a community scale
- Mitigate existing sites and sources of air and water pollution.

P2. Distribution and Transmission Grids

Ensure that electricity grid is ready for electrification related to peak load impacts and reliability.

This strategy builds on P1 by ensuring the grid is not only providing clean electricity, but reliable electricity to end users in the state. Increasing electrification in the building (Strategy B4) and transportation (Strategies T2, T3) sectors paired with a shifting electricity generation supply (Strategy P1) and a rise in distributed energy resources like rooftop solar (Strategy B5) means the transmission and distribution grid infrastructure in the state and broader region will require investment to expand and modernize grid systems and technologies to operate efficiently, effectively, and reliably.

KEY METRICS

All metrics for this strategy were included in modeling for Strategy P1

There are multiple facets to ensure reliability of electricity, including balancing the supply of intermittent resources to ensure consistent levels of power generation, in addition to reliably delivering that power and adjusting to real-time changes in demand and end-use conditions, such as availability of distributed resources. The transmission and distribution grid infrastructure in the region will require significant investment to be able to handle the influx of new grid-scale and distributed clean energy projects. Investment will be needed in both core grid infrastructure such as lines and substations, as well as grid modernization investments such as switches, sensors, and controls to improve the grid operator's visibility and operational flexibility. There will also be a need for investment in software systems to view information on distributed resource availability and enhance grid flexibility by utilizing distributed resources as virtual power plants.

Resulting Impacts

Environmental

Though not directly reducing emissions, this strategy will support P1 in ensuring that identified emissions reductions are reliably achieved. As a result, this strategy can indirectly reduce emissions of CO_2 and other GHGs, such as CH_4 and N_2O, that are associated with unabated fossil fuel combustion. In addition to GHGs, reducing the volume of natural gas combustion also reduces criteria pollutant emissions such as NO_x, SO_x, $PM_{2.5}$, and VOCs that are ground-level ozone precursors.

Economic

The implementation of grid improvements and manufacturing of related grid technologies could create many jobs in Pennsylvania. In addition, financial incentives in the IRA will mitigate a portion of the cost for some grid improvements, reducing the burden on ratepayers. Some manufacturing and utility jobs will also result from any construction of new grid infrastructure and will be retained over the long-term for operation and maintenance.

Social and Health

By supporting decarbonization of the power sector, this strategy indirectly improves air quality and also provides a benefit to public health by reducing gaseous and particulate emissions associated with fossil electricity sources, including criteria pollutants such as NO_x, SO_x, $PM_{2.5}$, and VOCs. Additionally, this strategy supports public health by ensuring that life-saving medical devices and critical facilities including hospitals, shelters, and warming and cooling centers reliably have access to the power they need, and people have access to heating and cooling, including in emergency situations. Grid reliability also mitigates other potential negative impacts of power loss such as refrigerated and frozen food spoilage, loss of productivity, increased crime, and creating or exacerbating unsafe and fear-inducing situations.

Implementation Considerations

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 Pennsylvania. Regulatory authority for utility investment in grid infrastructure is layered, with multiple levels of government from local to federal playing a role in siting, permitting, and cost allocation decisions for new transmission lines, and the state utility commission and regional transmission grid operator overseeing utility investments, grid modernization improvements, and distributed resource market participation policies. As such, the development of new transmission lines can take decades, with significant time and effort required for siting and permitting approvals at all levels. While there are efforts underway federally at the DOE and the FERC to help streamline much-needed transmission development, this is a significant barrier to the rapid development and integration of new clean energy resources in the Commonwealth and broader region.

The processes to approve expanded investments in the Commonwealth's transmission and distribution systems are complex, but the following actions can facilitate investments to improve grid reliability as part of implementing this strategy:

- Engaging with local communities to advocate for strategic siting and permitting of new transmission and distribution infrastructure.

RELATED FUNDING OPPORTUNITIES

Grid Innovation Program

The Grid Innovation program provides grants to support projects that use innovative approaches to transmission, storage, and distribution infrastructure to enhance grid resilience and reliability.

The first round of funding for the GRID Innovation program totaling $3.46 billion have been awarded.

Three (3) projects in Pennsylvania received funding with a total of approximately $170 million:

- PECO Energy Company ($100 million)
- PPL Electric Utilities Corporation ($49.5 million)
- Duquesne Light Company ($19.7 million)

- Supporting collaboration between transmission owners, operators, and planners to develop a regional plan and technology assessment to outline a pathway for grid infrastructure investment to support a net zero – and highly electrified – electric power system in 2050. The plan should identify opportunities for grid expansion that may have a more streamlined path to development, such as using existing rights of way, and review potential program and policy options to increase the use of non-wire alternatives to support grid reliability (e.g., vehicle-to-grid programs, virtual power plants with distributed solar and storage systems, or the strategic deployment of clean microgrids to serve concentrated load centers).
- Supporting transmission owners and operators in identifying funding and project support for the deployment of grid technologies and options that expand the capacity of current lines without needing to develop new transmission lines (such as the Grid Innovation Program). This includes reconductoring, which involves installing new, higher capacity wires on existing towers and structures, and the use of grid enhancing technologies to optimize electricity flow and maximize efficiency in the current system can contribute to increased grid reliability.

While the Commonwealth updates their distribution and transmission infrastructure and capacity, additional strategies can support the reliability of the grid:

- As noted in B5, distributed resources such as onsite solar – especially paired with distributed storage - can help reduce demand on the centralized power grid, therefore reducing the strain on transmission and distribution capacity. Onsite solar provides a decentralized source of renewable energy, often directly at the point of use.
- Actions to support electricity efficiency, as mentioned in B2, are also key to reducing strain on the power grid by reducing average end-user demand.

Partners and Participants

Key partners include:

- **FERC:** Responsible for approving or denying new transmission infrastructure projects. Works with the RTO to regulate wholesale electricity markets. Also oversees the National Interest Electric Transmission Corridor (NIETC) including stretches across the state.
- **US DOE:** Evaluates national transmission needs, develops tools for transmission analysis and planning efforts, and implements DOE policies and programs to support advance transmission deployment. Designates NIETCs for FERC to oversee.

- **PJM Interconnection:** The RTO that oversees Pennsylvania's and neighboring states (as well as Washington DC) electricity wholesale marketplace and wholesale generation interconnections while also overseeing transmission planning. Like other RTOs, PJM Interconnection is authorized by FERC to implement and operate the markets.
- **PA PUC:** Regulates the electric utilities and oversees the siting and construction of transmission lines once they are approved by FERC.
- **Electric Utilities:** Currently own the transmission and distribution infrastructure in Pennsylvania.

Financial Considerations

Depending on the lens from which this strategy is viewed, financial considerations vary.

Participant / Implementer Lens

To support upgrades to transmission, rate payers pay into a fund which can increase utility bills. Supplementing increased infrastructure for transmission and distribution with improved electricity efficiency and distributed solar can reduce the number of updates to transmission and distribution infrastructure that are needed.

The federal government has provided some funding through the IIJA to reduce the financial barriers to completing projects (see the Grid Innovation Program).

Equity & Environmental Justice

There is a need for workers in the power sector to enable updates to transmission and distribution. To prioritize equitable implementation, Pennsylvania could prioritize local communities for employment in jobs on transmission and distribution projects in the Commonwealth.

Special consideration should be given to how the costs and benefits of this measure are spread across utility customers, with particular focus given to low-income or otherwise disadvantaged communities, as well as more rural communities.

Waste Sector

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. According to the 2020 GHG inventory for Pennsylvania, approximately 2% of direct emissions were attributable to the waste sector. 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).

However, a broader, lifecycle view of waste and where waste comes from reveals that emissions associated with waste management are the tip of the iceberg and that tackling emissions provides significant benefits. Everything that is thrown away was at some point grown or produced and transported, using land, energy, water, and emitting GHGs at each step.

While lifecycle emissions are higher than direct emissions across nearly all sectors, the most noticeable change is in the scale of the waste management sector emissions.[35] Moreover, landfills, which are primarily used to manage waste have limited capacity and disposal is increasingly costly. Landfills also generate methane, a GHG with over 80 times the warming power of CO_2 (over a 20-year period).[36] Incinerators, which burn waste, often producing electricity in the process, are unwelcome in neighborhoods due to air pollution and the health and other impacts on overburdened communities. Opposition to new landfills and incinerators is common.

Pennsylvania is home to over 50 landfills that are large enough that they are required to report GHG emissions to the EPA.[37] These landfills receive waste generated in Pennsylvania, as well as from neighboring states. The municipal waste industry in Pennsylvania collected, hauled, and disposed of 9.6 million tons of municipal solid waste in 2021, or about 1,480 pounds per person. The most common landfilled materials in 2022 were food waste, film plastic, corrugated cardboard, compostable paper, and mixed paper.[38]

Recycling and reusing materials are methods to reduce the amount of waste generated. In 2021, more than 4.63 million tons of materials were collected and recycled, mitigating approximately 6.81 $MMTCO_2e$.[39] Recycling trends have been impacted by the

[35] Holly Lindquist et al. "Development of a Regional Greenhouse Gas Inventory and Forecast Including Direct and Consumption-Based/Energy-Cycle Emissions." n.d. https://gaftp.epa.gov/air/nei/ei_conference/EI20/session3/lindquist.pdf.
[36] "Understanding Global Warming Potentials." US EPA. n.d. Accessed May 22, 2024. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.
[37] "EPA Facility Level GHG Emissions Data," Accessed October 31, 2023, https://ghgdata.epa.gov/ghgp/main.do.
[38] "Waste & Recycling Facts." Pennsylvania Waste Industries Association. Accessed October 31, 2023. https://pawasteindustries.org/waste-recycling-industry/waste-recycling-facts/.
[39] "Statewide Recycling Data." PA DEP. Accessed October 31, 2023. https://www.pa.gov/agencies/dep/programs-and-services/waste-programs/recycling-in-pennsylvania/statewide-recycling-data.html.

COVID-19 pandemic and have varied by county, with almost two-thirds of counties in Pennsylvania reporting an increase in materials recycled and the remaining third reporting a decrease in recycling rates.

Given the challenges and consequences of current waste management practices, diverting waste from landfills and incinerators can result in GHG emission reductions and other environmental and socioeconomic benefits to Pennsylvania.

Strategies

Two strategies are proposed to address emissions from the waste sector, and these cover the following areas:

- W1: Sustainable Organic Waste Management
- W2: Sustainable Construction Waste Management

While the waste sector is an important emissions source, the emissions reductions from these strategies were not quantitatively modeled for the CAP.

Equity in the Waste Sector

Accessibility: Ensuring accessibility of waste programs to EJ areas should be sure to prioritize the **affordability** of program participation, minimizing costs to participate for low-wealth communities in particular. Additionally, waste management programs should aim to provide waste disposal resources and education materials in plain **language** with multiple translations available to maximize education efforts.

Advocacy: Numerous EJ areas face disproportionate pollution burdens, including for communities located near existing landfills and waste facilities. Advocating for these communities and ensuring outreach is conducted with them to account for their unique needs will be important in waste management efforts.

Accountability: Waste management procedures should be transparent, including the mechanisms by which waste is processed and where waste is stored. If necessary or accidental, any resulting toxins or pollutants released in land, air, or water should be distributed equitably based on usage to minimize adverse impacts in communities with lower resilience.

W1. Sustainable Organic Waste Management

Divert organic waste from landfills and incinerators.

KEY METRICS

Metrics for this strategy were not modeled.

Methane from landfills is produced by the decay of organic waste over time under anaerobic conditions (absence of air). The US EPA estimates that food waste comprises about 24% of solid waste from homes and businesses disposed of in landfills. Other organic matter, such as biosolids from wastewater treatment, leaves, yard waste, and agricultural waste also contribute to emissions from landfills and incinerators and are important to tackle. Pennsylvania can consider several initiatives to divert organic waste from landfills and incinerators by partnering with large food waste generators, such as grocery stores, institutions with cafeterias (education, hospital, nursing homes, business and government campuses), chain and other restaurants, large event venues (convention centers, arenas, art and music, catering halls), farmers, wastewater treatment operators, parks, and small-scale composting and community garden stewards.

Strategies used to divert organics from landfills and incinerators include laws to separate and beneficially use organic waste; incentivizing and removing barriers to food donation; expanding food donation and surplus recovery programs; increasing composting initiatives in the industrial, commercial, residential, and public/institutional sectors; and increasing the beneficial use of compost and biosolids (sludge).

Resulting Impacts

Environmental

This strategy will result in the reduction of both direct and lifecycle GHG emissions and will divert waste from landfills and incinerators. Additionally, this strategy will produce compost which can be used to improve soil health. Use of compost can also reduce the need for synthetic fertilizers.

Economic

Some of the economic benefits that would be achieved with this strategy include potentially lower disposition cost to waste generators and investment in a circular economy. This strategy could contribute to local job growth, particularly in green jobs.

This strategy will also reduce demand for new landfill and incinerator capacity and could generate a potential revenue stream for rural areas and farmers through the sale of compost. Lastly, the strategy will support existing organizations that focus on food insecurity and small-scale composting.

Social and Health

A reduction in waste will reduce air pollution, especially for communities at higher risk for air pollution impacts as most solid waste incinerators are located in EJ areas and emit air pollutants (e.g., particulate matter, nitrogen oxides, sulfur oxides). Reduced air pollution will reduce adverse impacts on health. As landfills pose a risk to soil and water contamination, reducing the amount of organics (especially food) in the residential and commercial waste set out curbside for disposal could also support efforts to deter disease-bearing pests, such as rats. Additionally, by incentivizing, removing barriers to, and expanding food donation, this strategy can lead to reduced food insecurity, a major concern in EJ areas. Partnering with organizations that meet core needs such as food security allows for an additional avenue for education about other relevant climate strategies.[40]

This strategy also provides a variety of opportunities to further increase social and health benefits. These include:

- Opportunity for partnership between urban and rural areas.
- Opportunity for bipartisan support and action at State and local levels.
- Opportunity for community participation, improved sense of place, and education on waste reduction and composting.

RELATED FUNDING OPPORTUNITIES

Composting and Food Waste Reduction Cooperative Agreements

CFWR cooperative agreements assist local and municipal governments with projects that develop and test strategies for planning and implementing municipal compost and food waste reduction plans.

The Cities of Philadelphia and Pittsburgh as well as the township of Haverford have received funding up to $90,000 per year since 2020.

Implementation Considerations

To successfully implement this organic waste management strategy, Pennsylvania could enact legislation, provide funding, and develop or support infrastructure and systems for organic waste management. Currently, sustainable organic waste management programs in Pennsylvania are voluntary. The following specific actions are recommended to implement this strategy.

[40] "From Field to Bin: The Environmental Impacts of U.S. Food Waste Management Pathways." US EPA. n.d. https://www.epa.gov/land-research/field-bin-environmental-impacts-us-food-waste-management-pathways.

- Enact laws to require industrial, commercial, and residential separation of organic waste and support organics collection and management.[41]
- Develop model ordinances for municipalities to adopt, such as restricting the quantity of organic waste businesses and residents can send to landfills or requiring local agencies to provide technical support for organics waste management programs and infrastructure.
- Encourage food donation through expanded tax deductions or credits or strengthened state liability protection. This could be accomplished by expanding Pennsylvania's existing tax credit for the Charitable Food Program. Developing food safety laws and guidance regarding food donations can also create clarity and encourage more food donations.
- Facilitate the permitting and development of large-scale composting facilities within the State.
- Establish educational, partnership, and pilot programs to expand current organic waste management efforts locally and statewide.
  - Encourage the development of educational and pilot programs with universities, schools, hospitals, nursing homes, and other institutions, such as the Millcreek Township pilot organic waste collection program.[42]
  - Facilitate partnerships between organic waste generators and farmers to encourage land application and composting.
  - Increase biosolids land application training programs, and update protocol for biosolids management in alignment with US EPA guidance.
  - Develop educational programming to increase public awareness of compost benefits (including reduced air pollutant emissions and public health), land application, and food expiration and best by date labels, to improve organic waste management and reduce food waste.
  - Provide incentives and/or rebates for home composting including tabletop and yard composters.

Example Sustainable Organic Waste Management Program: Millcreek Township Residential Compost Programs:

Millcreek Township in northwest Pennsylvania offers complimentary curbside leaf and brush collection for residents. The township partners with Millfair Compost Center, where material is composted and can also be dropped off by residents.

In 2022, Millcreek Township also piloted a subscription composting program for residents in partnership with Conservation Compost. Although a fee is associated with the program, residents may recoup costs through the municipality's pay-as-you-throw trash collection program.

Millcreek Township's programs provide an example of potential partnership programs that can reduce the quantity of organic waste entering landfills.

[41] Similar laws have been enacted in other municipalities and states, including New York City, NY, Boston, MA, Boulder, CO, Austin, TX, and California.

[42] "New Food Composting Program Is Open to All Erie County Residents." n.d. Accessed May 22, 2024. https://www.goerie.com/story/news/local/2022/04/02/new-food-composting-program-is-open-to-all-erie-county-residents/65347315007/.

Partners and Participants

Implementing a sustainable organic waste management program will require cooperation between a variety of interested parties. Key partners include:

- **Pennsylvania legislators:** The PA General Assembly establishes State laws and can create legislation that supports organics recovery and management.
- **Pennsylvania agencies:** Numerous agencies could play a role in implementing this strategy. For example, DCNR manages Pennsylvania's state parks and forests and oversees conservation programs and grants. DCNR can demonstrate best practices in organics material management and support pilot projects and grants. PDA oversees the State's agricultural industry and can support organic waste reduction, surplus recovery programs, energy generation through biodigestion, and encourage land application and composting. DCED provides resources and technical assistance for sustainable community and business development and local planning initiatives that could support organics management business ventures and related infrastructure. The Pennsylvania Department of Education can promote organic waste reduction in schools and support pilot programs and research.
- **Households and residential building owners:** Individual home and building owners will play a role in this strategy by separating and collecting compost for collection or at-home composting efforts.
- **Food service businesses and institutions with cafeterias:** Food service businesses and other entities that provide or serve food, such as schools, colleges, and hospitals, play a crucial role in reducing food insecurity and expanding the collection and disposal of organic waste. Food service businesses and institutions can advocate for incentives to support food rescue to address food insecurity and participate in local food rescue programs. Some food service businesses and institutions with cafeterias also process compost onsite, while others work with organic waste management organizations to sustainably manage organic waste. Entities that do not have such programs can begin to implement them in partnership with local composting businesses.
- **Community composting sites:** Municipally supported or volunteer organized community composting sites provide opportunities for residents to participate in composting locally. These entities play a vital role in the education and promotion of local sustainable organic waste management.
- **Composting businesses:** Pennsylvania has numerous businesses that collect and process compost for businesses and residents for a fee. These entities are creating necessary infrastructure to support the expanding organics waste management sector. Continued growth and expansion of these businesses can support municipalities in developing wide-scale composting for residents.

- **Producers and grocers:** Producers and grocers are vital in supporting sustainable waste management of organics and addressing food waste reduction. Producers and grocers manage large quantities of organic material, some of which may be composted or anaerobically digested. These entities can also lead initiatives to reduce food insecurity thereby limiting the quantity of food processed as waste.

Financial Considerations

Participant Lens

- **Voluntary measures:** Individual households or organizations can voluntarily support sustainable organic waste management. Individual households may choose to compost independently, donate food scraps to community organizations or composting sites, or subscribe for organic waste collection and composting with local businesses or nonprofits. Costs for programs that are not free typically range from $5-25 per month for weekly collection of five gallons of food scraps.[42,43] Similarly, organizations, including businesses and nonprofits, can choose to sustainably manage organic waste onsite or through an organic waste management company. In 2023, Lafayette College in Lehigh Valley, PA invested $150,000 in a commercial composting vessel that can process 1,200 lbs. of organic waste each day.[44] Sustainable organic waste management measures may require financial investments, which could deter voluntary participation or require financial incentives.
- **Required by legislation:** Mandated organic waste management measures could become cost prohibitive if service provider costs are high, particularly for restaurants, small businesses, and organizations. Providing tax incentives for these entities to reduce organic waste through food rescue and donation could reduce net costs to participants for complying with required organic waste management. Currently, Pennsylvania offers a tax credit that is valued at 55% of the total contribution to eligible organizations.[45]

Implementer Lens

Government entities and large organizations can support the implementation of a sustainable organic waste management strategy by providing funding or incentives. Funding opportunities may include grants to expand food donations, as well as funding for surplus food recovery efforts, such as the Pennsylvania Agricultural Surplus System. The State could also provide incentives (such as grants, loans, and tax credits) for municipalities to support residential organic management programs and to benefit organizations that participate in sustainable

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43 "Residential Composting Service - Ardmore, Narberth, Merion, Wynnewood, Haverford, Bryn Mawr." Mother Compost (blog). n.d. https://mothercompost.com/residential-composting/.

44 "Lafayette College's Commercial Composter Aims to Increase Sustainability on Campus." LehighValleyNews.Com. November 7, 2023. https://www.lehighvalleynews.com/environment-science/lafayette-college-has-a-new-150k-commercial-composter-heres-how-it-works.

45 "Pennsylvania Food Waste Policy." Rethink Food Waste (ReFED). n.d. http://policyfinder.refed.org/pennsylvania/#tax-incentives.

organics waste management. In addition to operational costs, there are costs associated with program design, administration, evaluation, and education. Since 2020, Philadelphia, Pittsburgh, and Haverford have received $90,000 in funding for organic waste reduction programs. The USDA Office of Urban Agriculture and Innovation Production planned to award $10.2 million to fund pilot projects to improve organic waste solutions with a focus on local governments, school districts, and Native American tribes.[46] This and similar federal funding opportunities can reduce the burden of sustainable waste management incentive programs for Pennsylvania and local governments.

Government agencies can also fund and facilitate (e.g., through expedited permitting) the design and implementation of infrastructure to support sustainable organic waste management. Infrastructure may include anaerobic digesters, composting facilities, and programs for food recovery. In 2017, Washington DC Department of Public Works estimated that an aerated static pile composting facility that could process 150,000 tons of organics per year would cost between $7-11 million.[47] These programs also require waste collection and maintenance fees. In Boston, the universal residential composting program requires the city to invest less than $11 per household each month in addition to a $32 per household startup cost.[48]

Equity & Environmental Justice

The development and implementation of a more sustainable organics waste management strategy will reduce health inequity. Access to food for food-insecure individuals can improve health outcomes and access to basic needs. Furthermore, reducing disposal of organics managed through landfills and incinerators can provide local air quality and health benefits and global climate benefits. The sustainable organic waste management strategy aligns with the USEPA hierarchy of wasted food pathways based on lifecycle and circularity assessments, which prioritizes the distribution of excess food to those who need it.

[46] "Funding Opportunities." USDA. n.d. https://www.usda.gov/foodlossandwaste/funding.
[47] RRS. Compost Feasibility Study. Commissioned by District of Columbia Department of Public Works. April 2017. https://dpw.dc.gov/sites/default/files/dc/sites/dpw/page_content/attachments/DC%20Compost%20Feasibility%20Study_vf_0417.pdf.
[48] "Boston Touts Initial Success of Composting Program as It Plans Expansion to 20K Households." Waste Dive. n.d. Accessed May 22, 2024. https://www.wastedive.com/news/boston-organics-compost-save-that-stuff-garbage-to-garden/642329/.

W2. Sustainable Construction Waste Management

Support construction material salvage and reuse along with adaptive reuse of buildings.

PADEP estimates that construction and demolition (C&D) waste and debris constitutes approximately 17.5% of waste generated in Pennsylvania.[49] Additional C&D materials (uncontaminated soil, rock, stone, gravel, brick and block, concrete and used asphalt, waste from land clearing, grubbing and excavation, including trees, brush, stumps and vegetative material) when separated and used for clean fill are not accounted for in this percentage. Other than wood, construction materials decay less rapidly than organics and therefore do not directly generate as much methane as organic materials generate when disposed of at landfills. However, through construction material salvage and reuse as well as adaptive reuse of buildings, Pennsylvania has the opportunity to reduce the need for raw materials, thereby lowering its "embodied carbon" footprint. Embodied carbon refers to the amount of GHG emissions associated with the raw material extraction, product manufacturing, and transport stages of a product's life. Reducing embodied carbon from construction materials, such as concrete, asphalt, and steel should be considered. USEPA notes that the manufacturing of construction materials and products accounts for 11% of annual global GHG emissions, and that reducing embodied carbon from construction materials is essential to effectively addressing climate change.[50]

KEY METRICS

Metrics for this strategy were not modeled.

Initiatives within this climate strategy include expanding and incentivizing existing frameworks for low-carbon and salvaged materials, supporting the development and standardization of environmental product declarations (EPDs), designing and building for easier deconstruction, and enabling building ordinances that encourage adaptive reuse.

Key partners for this strategy include government agencies that manage large infrastructure construction projects, developers, architects, engineers, construction companies, historic preservation organizations, municipalities looking to implement embodied carbon policies and ordinances, organizations that are already developing tools for EPDs and lifecycle carbon accounting (such as the Carbon Leadership Forum, American Institute of Architects, US Green Building Council), and more.

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[49] "Construction and Demolition Waste." PA DEP. n.d. https://www.pa.gov/agencies/dep/programs-and-services/waste-programs/solid-waste-programs/municipal-waste-program/construction-and-demolition-waste.html.
[50] US EPA, OCSPP. 2023. "What Is Embodied Carbon?" Overviews and Factsheets. https://www.epa.gov/greenerproducts/cmore.

Resulting Impacts

Environmental

This strategy will benefit the environment through reduced GHG emissions. Embodied emissions will be reduced as will emissions resulting from the transport and disposition of material at landfills. Through reuse of materials, the strategy will also reduce the need for raw material extraction and product manufacturing along with the emissions resulting from these activities.

This strategy will also support a growing circular economy and green jobs.

Economic

Better management of construction wastes incentivizes waste reduction and can support local economies and job growth in the areas of material salvage, adaptive reuse, and deconstruction. It will also reduce costs in the construction industry by salvaging existing buildings, infrastructure, and construction materials.

Social and Health

This strategy will reduce emissions of air pollutants and will improve health by reducing the need to extract, transport, and manufacture construction materials and potentially by reducing emissions associated with building demolition. Additionally, embodied carbon reduction in construction materials can be achieved through industrial process changes that reduce the use of fossil fuels and chemicals consumed in the creation of traditional building materials. This will benefit all people, especially those in overburdened communities, by reducing impacts to air quality and health. The strategy will reduce the quantity of waste disposed, thereby slowing the need for new or expanded landfills, which in turn minimizes displacement and activities that reduce neighborhood desirability. Historic preservation efforts are also supported by this strategy through added incentives for adaptive reuse. Historic preservation has many benefits including maintaining neighborhood historic fabric and cultural sense of place.

RELATED FUNDING OPPORTUNITIES

IRA embodied carbon efforts

The IRA provides EPA with the funds to develop a program to label construction materials and products that have substantially lower embodied GHG emissions and provide grants and technical assistance for environmental product declarations (EPD).

GSA was given $2.15 billion to acquire and install low embodied carbon materials and products, DOT FHWA was given $2 billion to reimburse or provide incentives for the use of low embodied GHG materials and products, and HUD was given $837.5 million for direct loans to affordable housing climate resilience projects with low embodied emissions materials and products.

DOE has nearly $16 billion for financial assistance and tax credits to help materials and products manufacturers reduce embodied GHG emissions from those materials and products.

Implementation Considerations

By growing existing initiatives, and leveraging federal funding opportunities, incentives, and resources, the implementation of sustainable construction waste management can create social, health, environmental, and economic benefits. The following actions could be taken to implement this strategy:

- Leverage existing initiatives in the government, nonprofit, and professional organization sectors. The US Green Buildings Council provides resources to evaluate the benefit of material reuse in building construction. Government and other interested parties also provide information on material reuse centers that could be helpful for construction and engineering companies to partner with.[51]
- Leverage IRA funding to reduce embodied carbon of construction materials and IIJA funding to increase education and opportunities for recycling and waste management in the construction sector.
- Develop model ordinances to require certain buildings to include a minimum amount of reused materials and the salvage of high-embodied carbon and reusable material types during demolition.
- Expand statewide codes relating to beneficial reuse of materials to provide more clarity on material reuse for construction, thereby encouraging the reuse of material. For example, Title 25 Chapter 290 of Pennsylvania's Code regulates the Beneficial Use of Coal Ash, establishing standards for the physical characteristics of coal ash, appropriate beneficial uses, and monitoring requirements.
- Develop incentives or regulations to reduce embodied carbon in construction materials purchased for government contracts.
- Develop educational materials, tools, and best practices in partnership with existing partners, such as the Green Building Council and USEPA Comprehensive Procurement Guideline Program to provide accessible and reliable information on the reuse of C&D materials. Connect groups of interested parties to enable information exchange and facilitate logistics of lowering embodied carbon to encourage the construction industry to adopt more sustainable practices.

Example Sustainable Construction Waste and Adaptive Reuse Program:

The City of Philadelphia passed three bills in 2019 to incentivize adaptive reuse of historic buildings. An amendment to Title 14 of The Philadelphia Code allows for certain historically designated properties to be redeveloped for residential reuse. Another authorizes accessory dwelling units on historic single-family properties. An amendment to Title 14 also reduces parking standards for historically designated properties.

In addition, an amendment to Chapter 19 of Philadelphia's code reduces the property tax abatement over a period of 10 years on new construction. Modifications to or adaptive reuse of existing buildings for residential use will continue to receive a full 10 year tax abatement.

[51] "C & D Salvaged Material Outlets." Department of Environmental Protection. n.d. Accessed May 23, 2024. https://www.dep.pa.gov:443/Business/Land/Waste/SolidWaste/MunicipalWaste/Construction-Demolition-Waste/Pages/C_DSalvagedMaterialOutlets.aspx.

Partners and Participants

Implementing a sustainable construction waste management program will require partners and interested parties from various sectors to work together. Key partners include:

- **Pennsylvania Department of General Services:** The Department of General Services oversees non-highway capital projects and State-owned real estate. This includes C&D of capital projects.
- **PA DCED:** PA DCED provides resources and technical assistance for sustainable community and business development and local planning initiatives that could support construction recycling business ventures and related infrastructure.
- **Pennsylvania Infrastructure Investment Authority (PENNVEST):** PENNVEST provides financing for drinking water, wastewater, stormwater, and non-point source pollution infrastructure projects and could require or incentivize awardees to use recycled materials and recycle C&D debris resulting from PENNVEST-financed projects.
- **PennDOT:** PennDOT oversees the maintenance and improvement of state and local highways, and bridges, including C&D. PennDOT can support the growth of a circular economy for construction materials and reduce the embodied carbon associated materials, for example through the use of recycled asphalt pavement or recycled concrete aggregate.
- **Pennsylvania Turnpike Commission:** The Turnpike Commission oversees design and construction projects on the Pennsylvania Turnpike, and commits to taking into account economic, environmental, and social impact in their work.

Financial Considerations

The US EPA's 2020 Recycling Economic Information Report estimated that, in 2012, Construction & Demolition recycling was a major contributor to the economic impact of recycling in the United States, generating approximately $10 billion in wages, $1 billion in taxes, and 175,000 jobs.[52] The analysis found that a large proportion of the sector's economic impacts occurred indirectly, or upstream.

Participant Lens

- **Voluntary measures:** Participation from construction and design industry may incur initial cost increases while companies modify their construction waste management practices. If the construction sector is not incentivized to participate in sustainable construction waste management practices through preferred contracting or material rebates, the higher upfront costs associated with implementing this strategy may deter participation. However, costs of recycling and using recycled C&D materials can be offset by reducing transportation

[52] "Recycling Economic Information Report." US EPA. 2020. https://www.epa.gov/sites/default/files/2020-11/documents/rei_report_508_compliant.pdf.

and material disposal costs. Recovered materials sent to qualified 501(c)(3) charities may be included as donations in tax deductions.[53] Reusing material between projects can be financially beneficial to construction companies and purchasing salvaged material may be cheaper than purchasing virgin material.

- **Required from legislation:** State and federal requirements may limit the type and quantity of salvaged material used in construction projects, which may result in additional costs when sourcing materials from different manufacturers. Required investments in C&D processing equipment and capacity, in addition to rising labor and transportation costs, may put financial strains on small waste recycling businesses.[54] However, laws that require material recycling can lead to increased economic activity—jobs, revenue, and investments increase as transfer and processing capacity for materials increases.[55] A 2020 Economic Impact Study on C&D Diversion Requirements in Austin, Texas found that the city's diversion ordinance had a minimal impact on the cost of developing residential and commercial projects.[56]

Implementer Lens

For municipal, state, and federal entities, developing programs with sufficient administration, management, and evaluation support may require funding additional to that set aside for grants and direct program costs, such as through the IIJA and IRL.

Equity & Environmental Justice

The shift to a more sustainable approach to construction waste can be paired with a framework for affordable housing through adaptive reuse of buildings and use of recovered and low-embodied carbon construction materials to serve Pennsylvanians more equitably. Recycling C&D debris benefits EJ areas by reducing the disposal and incineration of material, as disposal facilities are often sited in EJ areas. When waste is landfilled or incinerated, nearby communities are exposed to odor and noise pollution, air pollution from trash trucks, waste incineration, and disposal, and soil and water pollution from landfills. Finally, sustainable construction management can be used to provide training and green job opportunities in EJ areas.

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[53] US EPA, OCSPP. 2023. "What Is Embodied Carbon?" Overviews and Factsheets. https://www.epa.gov/greenerproducts/what-embodied-carbon.
[54] "The Fragile Ecosystem of Massachusetts C&D Recycling." Waste Dive. n.d. https://www.wastedive.com/news/massachusetts-boston-construction-waste-recycling-/634300/.
[55] "Commercial Food Material Disposal Ban." Commonwealth of Massachusetts. n.d. https://www.mass.gov/guides/commercial-food-material-disposal-ban.
[56] "Economic Impact Study on C&D Diversion Requirements." Austin Resource Recovery. 2020. https://www.austintexas.gov/sites/default/files/files/FINAL%20Economic%20Impact%20Study%20on%20C%26D%20Diversion%20Requirements_06-02-20.pdf.

Land Use and Agriculture Sector

The land use and agricultural sector includes agricultural lands and 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 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 increased soil health, biochar or compost application to soils, and more. Additionally, GHG emissions from agriculture can be reduced by strategies such as use of enhanced efficiency fertilizers and including livestock feed additives to reduce methane emissions from enteric fermentation.

Pennsylvania enjoys diverse and widespread forests that cover 16.6 million acres of land, or about 57% of all land in the Commonwealth.[57] 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 recreational 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 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.

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

[57] "Forests of Pennsylvania, 2019." USDA. 2020. https://www.fs.usda.gov/nrs/pubs/ru/ru_fs251.pdf.

flowers, poultry, dairy products, cattle, and pigs.[58] In 2022, there were approximately 52,700 farms and ranches spread across 7.3 million acres.[59] Lancaster, Bradford, Franklin, York, and Berks counties have the most acres of farmland in Pennsylvania.[60]

Strategies

The strategies proposed to address agriculture emissions reflect existing technological and policy trends that aim to implement agricultural best practices and increase natural carbon sequestration through land and forest management. Two strategies are modeled, covering the following areas:

- L1: Agricultural Best Practices- Emissions Reduction
- L2: Agricultural Best Practices- Carbon Sequestration
- L3: Land & Forest Management

Together, the modeling results indicate that these strategies will reduce emissions compared to the Reference BAU in 2030 and 2050 and in 2050 will reduce emissions in the agriculture sector by 3.96 $MMTCO_2e$.

Table 16. Agriculture sector GHG reduction strategies and associated reductions ($MMTCO_2e$)

GHG Reduction Strategy	2030	2050
L1. Agricultural Best Practices – Emissions Reduction	0.02	0.02
L2. Agricultural Best Practices – Carbon Sequestration	1.52	2.78
L3. Land & Forest Management	1.14	1.16

For each strategy, the environmental 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 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.

[58] 2017 Census of Agriculture State Profile: Pennsylvania. USDA. n.d. https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Pennsylvania/cp99042.pdf.
[59] 2020 State Agriculture Overview: Pennsylvania. USDA. 2023. https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=PENNSYLVANIA.
[60] 2017 Census of Agriculture State Profile: Pennsylvania. USDA. n.d. https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Pennsylvania/cp99042.pdf.

Equity in the Land Use Sector

Accessibility: Two of the strategies in the land use sector relate directly to rural and agricultural communities. Connecting with these communities for outreach can be challenging due to **physical** challenges such as remote location and long transportation distances, **technology** challenges such as unreliable or insufficient internet access, and **lack of existing relationships** and methods to reach these communities.

Increasing internet access for rural areas and establishing outreach methods to specifically target rural communities could help improve accessibility. Such methods would need to account for travel distances and provide backup options for those who do not have sufficient internet access to join virtual meetings or whose cultural practices are not compatible with technology-enabled communication systems.

Advocacy: Particular attention should be placed on how strategies will impact farmers and other agricultural workers of small farms, and those others who work, live, and go to school in proximity to agricultural processes. To prioritize the wellbeing of all constituents in efforts addressing land use, DEP should continue to communicate and engage with communities facing EJ issues to advocate for climate actions of most interest to the community. Additionally, DEP could partner with CBOs and collaborate with other agencies such as DCNR to amplify existing outreach and land use climate actions.

Accountability: To ensure accountability, it will be important to identify intended outcomes and benefits, monitor actions that have been implemented in the land use sector, review impacts and progress on commitments, share updates with interested community parties, and incorporate feedback following a dynamic and predetermined cadence.

L1. Agriculture Best Practices – Emissions Reduction

Implement agriculture best practices for GHG emissions reductions.

This strategy includes trainings and tools to implement agricultural best practices focused on reducing the amount of GHGs emitted by farmlands, such as through feed additives, nitrification inhibitors, manure management, and energy efficiency measures in agricultural management.

Dietary supplementation with feed additives in has the potential to significantly reduce GHG emissions from dairy cattle by inhibiting methane producing microbes in the rumen. The modeling for this strategy addressed two types of feed additives for their emissions reduction potential: nitrate and 3-Nitrooxypropanol (3-NOP). Feed additive products containing nitrate are currently available in the US, however, 3-NOP is still undergoing FDA review. This model assumes that 3-NOP would be FDA approved in 2024, based on a review of recent news. According to draft guidance by the USDA, Nitrate and 3-NOP feed additives have an emissions reduction potential of 17.7%, however this will be highly variable with dry matter content of animal feed.[61] Per the California Air Resources Board, transitioning from [current] feed additives to 3-NOP has an emissions reduction potential of 20-50%, and 10-20% for nitrate additives.[62]

Nitrification inhibitors slow the process of denitrification in which ammonia or urea convert to nitrate in soil. As a result, less nitrogen is lost to nitrous oxide formation or leaching/runoff. Nitrification inhibitors can help to increase the amount of plant-available nitrogen in soils by slowing the conversion of ammonium to nitrate. This can potentially reduce the total amount of synthetic fertilizers farmers need to apply. Because ammonia-based fertilizers constitute 90% of the nitrogen fertilizers sold in the US, it was assumed that 90% of the fertilizers used in PA would be compatible with nitrification inhibitors.

GHG METRICS

GHG emissions reductions:

2030: **0.02 $MTCO_2e$**
2050: **0.02 $MTCO_2e$**

Cost (or benefit) per ton $MTCO_2e$/reduced): **\$17/$MTCO_2e$**

[61] "Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory." USDA. 2023. Table 4-6.
[62] "Analysis of Progress toward Achieving the 2030 Dairy and Livestock Sector Methane Emissions Target. Draft." California Air Resources Board. 2021. https://ww2.arb.ca.gov/sites/default/files/2021-06/draft-2030-dairy-livestock-ch4-analysis.pdf.

Resulting Impacts

Environmental

Livestock operations can contribute to local air quality issues, particularly around large, confined animal feeding operations. By reducing methane emissions, these additives may also lead to a decrease in other harmful air pollutants associated with manure management.

By keeping nutrients available for plant uptake for a longer period, enhanced efficiency fertilizers can promote healthy soil microbial communities, leading to better soil structure and fertility. Nitrification inhibitors may also indirectly reduce the amount of nitrogen lost to leaching or runoff, which in turn reduces nitrogen loading into water sources. Over-loading water bodies with nitrogen can lead to eutrophication and ultimately anoxic conditions which kill aquatic plants and fish.

Economic

The adoption of new feed additives is expected to have a net negative economic impact. Under this strategy, farmers are asked to pay more for feed additives which do not increase productivity or quality of product, and which may harm their cattle when incorrectly administered. Because 3-NOP is not yet FDA approved it is also unclear how much it will cost in the United States once approved.

While nitrification inhibitors are also an added expense for farmers, their use may help farmers meet their crop nutrient needs with less fertilizer. The exact extent to which nitrification inhibitors may reduce nitrogen application rates is unknown and will likely vary depending on field conditions.

Social and Health

Nitrate feed additives administered to cattle in high concentrations may lead to adverse health outcomes including reduced blood oxygen content, weight loss, reduced milk production, and miscarriage. However, based on preliminary reports and reviews from international research entities there are no adverse health outcomes for dairy cattle associated with 3-NOP. Reduced methane emissions will improve the local air quality by reducing the emissions of criteria air pollutants and allergens. Lower criteria for air pollutant emissions can lead to a better quality of life for farmers and others who live in the area.

RELATED FUNDING OPPORTUNITIES

Climate Smart Agriculture and Forestry

The IRA has provided an additional $19.5 billion in funds for the National Resources Conservation Service (NRCS) to accept more projects under four existing conservation programs such as the agricultural conservation easement program, the conservation stewardship program, the conservation reserve program, and the environmental quality incentives program.

By decreasing the amount of nitrogen lost to leaching and runoff, nitrification inhibitors can reduce nitrate pollution of ground and surface waters which may be used for drinking water, especially in rural communities. In high concentrations, nitrates in drinking water may be toxic to humans and, in extreme cases, cause blue baby syndrome which can be fatal.[63]

Implementation Considerations

The success of feed additives as an emissions reduction tool depends heavily on adoption by farmers, which, at present, is unincentivized due to higher costs for no productivity reward. 3-NOP is not yet FDA approved, though it is approved for use in the European Union and elsewhere. Moreover, not all fertilizer types are compatible with nitrification inhibitors. Implementation considerations include lowering barriers to adopt feed additives and nitrification inhibitors, integrating additional emissions reduction pathways like energy efficiency in management and equipment, and ensuring appropriate enforcement of water protection measures.

Agriculture can also support building emissions reductions by providing inputs for climate smart materials for use in high performance buildings. Examples include hardwoods, industrial hemp, and flax, all of which sequester carbon.

The following actions could be taken as part of implementing this strategy.

- Reduce GHG emissions through feed additives, enhanced efficiency fertilizers, fertigation, and improved manure management.
- Incentivize adoption of nitrification inhibitors and feed additives via subsidies.
- Conduct outreach and education to agricultural networks on the societal and environmental benefits of methane-reducing feed additives, which may otherwise present little to no advantage to farmers.
- Encourage installation of manure digesters to reduce on-farm emissions.
- Encourage adoption of energy efficiency measures in agricultural operations, such as in machinery and energy sourcing: EnSave complementary program offerings including promotion of energy audits, incentive funds, low-interest recovery loan fund, competitive grants for energy efficiency projects, which may be particularly useful for dairy and poultry operations, which have higher energy usage in operations.
- Introduce agricultural insurance requirements to factor climate risk reduction benefits of management best practices

[63] Knobeloch et al. 2000. "Blue babies and nitrate-contaminated well water." Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1638204/.

- Support research and development of agricultural practices that will reduce emissions, with regard for crop rotations, machinery, and operations.
- Expand state requirements on manure management and separation of livestock from waterways, beyond existing regulatory requirements from EPA, to address health concerns related to nitrate use.

Partners and Participants

Key partners include:

- **PDA:** PDA may offer oversight, funding opportunities, and dissemination of resources for landowners to manage carbon and reduce emissions.
- **Farmers Associations and Agricultural Groups:** Engage with farm coalitions and agricultural groups to understand obstacles and opportunities in feed additive adoption, manure management, fertigation, and no-till practices. Sustainability-oriented groups like Pasa Sustainable Agriculture offer trainings, technical assistance, and other resources throughout Pennsylvania's farming community. As dairy and poultry offer the most significant opportunities for energy savings in farm operations, seek out dairy and poultry coalitions specifically.
- **Insurance companies:** The introduction of agricultural insurance requirements that consider climate risk could encourage adoption of emissions-reducing agricultural practices.
- **Universities and research institutions** who may investigate and develop further best practices for emissions reductions in farm operations.
    - **University Extension Services,** such as Penn State Extension. These bodies can partner with the state to conduct farmer trainings and surveys and provide lab-based soil testing and other highly valuable tools and resources.
- **The Chesapeake Bay Program Office:** CBPO is a multi-agency partnership executing strategies for nitrogen emissions reduction in the Bay, as well as county-level plans for localized watershed restoration. The Program may provide valuable research and implementation capacity to the State for reducing pollution and emissions from agricultural practices, including conservation tillage, cover crops, forest buffers along farm edges, streamside fencing to reduce manure runoff, broader manure and litter management, and site-specific nutrient management planning.

Financial Considerations

The transition to using feed additives or nitrification inhibiting fertilizers is not necessarily cost-effective for farmers. Nitrate feed additives tend to be more expensive, and 3-NOP will likely be expensive when they enter the market after FDA approval. The most significant barriers to implementation of these programs are the relative costs of management changes, and the volatile business environment in which farms already operate. Depending on the lens from which this strategy is viewed, financial considerations vary.

Participant Lens

- **Voluntary measures:** Farm-level actions to reduce emissions can have high cost or opportunity cost. To change management plans for conservation tillage, cover cropping, and nutrient management planning, farms must undergo significant analysis of present operations and additional workforce training. Development of animal waste storage systems, transport of excess manure, and exclusion of livestock from stream access require additional operating costs, with no direct monetary benefit to the farm. Ideally, grant funding and tax incentives may encourage farm-level action.
- **Programmatic**: Grant funding and tax incentives can encourage farm-level action where high capital or opportunity cost would otherwise make the transition to reduced tillage and stricter manure management difficult.
- **Required from legislation**: Higher standards for feed additives, manure management programs, and energy-efficient fertilizers may lead to higher purchasing and equipment costs, and limit choice in purchasing decisions.

Implementer Lens

Farms that implement nutrient and manure management programs will experience costs associated with program startup, administration, and workforce training. As a result, farms may need to seek additional funding to support additional hiring and program management. PA DOA could establish a network of farms to share lessons learned or reduce costs and stress by offering technical assistance or pooling program resources.

Equity & Environmental Justice

To transition to nitrate or nitrification inhibiting feed additives for emissions reduction, and integrate energy efficiency into agricultural operations, farmers will face significant capital cost. Within an already economically unstable industry, smaller farmers may not have the time, money, or capacity to invest in such transitions. Grant funding, availability of technical and programmatic assistance, and built coalitions or networks of farmers by region may ease the transition for smaller farmers. Women and minority-owned farmers should have ready access to information and subsidies for methane-reducing feed additives.

L2. Agriculture Best Practices – Carbon Sequestration

Implement agriculture best practices for carbon sequestration.

This strategy includes trainings and tools to implement agricultural best practices, such as those focused on no-till farming practices, to increase the amount of carbon sequestered by farmlands. Practices could include cover cropping, rotational grazing, silvopasture, and organic and regenerative agricultural methods, which increase soil health and capacity for long-term sequestration. 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 2021 CAP. In 2023, the modeling for this strategy addressed reduced tillage acreage in addition to no-till acreage, seeing higher sequestration potential in no-till acreage. Tillage practices by crop are based on a survey of Pennsylvania farmers conducted by USDA for 2013 and 2014[64] and the 2022 State Agriculture Overview for Pennsylvania.[34] The modeling for this strategy 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.

KEY METRICS

GHG emissions reductions:

2030: **1.52 $MMTCO_2e$**
2050: **2.78 $MMTCO_2e$**

Cost (or benefit) per ton $MTCO_2e$/reduced):
$5,339/$MTCO_2e$

Resulting Impacts

Environmental

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

[64] "Tillage Practices with Updated Alfalfa Seedings and Final Acreages." USDA. https://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Survey_Results/
[34] "State Agriculture Overview - Pennsylvania." USDA. 2022. https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=PENNSYLVANIA.

associated with fuel combustion, including criteria pollutants such as NO_x and SO_2. Reducing tillage for increased carbon sequestration may also reduce flood risk by enabling soils to hold more water, making farms more resilient to projected increases in flood risk.

Economic

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 costs associated with machinery related to no-till or air seeding practices. Some cost savings may be also realized as crop yields may increase after soil health practices are implemented. However, on the net, the economic impacts are expected to be negative.

Social and Health

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

Implementation Considerations

The following actions could be taken as part of implementing this strategy:

- Provide information, tools, and resources for farms to implement reduced tillage practices, including cover cropping.
- Conduct outreach and education through DEP and other state actors to facilitate no-till and other soil management practices for increased sequestration, and the environmental benefits (e.g., GHG reductions, improved soil health, long-term resilience) of reducing tillage outside of cost savings and decreased fuel consumption.
- Inform farmers on how and where to buy and implement no-till technologies, which are already available on the market.
- Provide incentives for no-till farming and air seeding, such as tax credits or rebates for farms that invest in related equipment, or grant funding for equipment and workforce development.

RELATED FUNDING OPPORTUNITIES

Climate Smart Agriculture and Forestry

The IRA has provided an additional $19.5 billion in funds for the National Resources Conservation Service (NRCS) to accept more projects under four (4) existing conservation programs such as the agricultural conservation easement program, the conservation stewardship program, the conservation reserve program, and the environmental quality incentives program.

- Support research and development of agricultural practices that will sequester Carbon on-farm.
- Provide tax assessment program to encourage protection of farmland, forestland, and open space for carbon sequestration.
- 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.
- Promote practices that diversify and enhance long-term forest cover and health on farmlands, therefore increasing carbon sequestration and storage.

Partners and Participants

Key partners include:

- **PDA:** Conduct oversight, funding opportunities, and dissemination of resources for landowners to manage carbon and reduce emissions.
- **Farmers Associations and Agricultural Groups:** Engage with farm coalitions and agricultural groups to understand obstacles and opportunities in manure management, fertigation, and no-till practices. Sustainability-oriented groups like Pasa Sustainable Agriculture offer trainings, technical assistance, and other resources throughout Pennsylvania's farming community. As dairy and poultry offer the most significant opportunities for energy savings in farm operations, seek out dairy and poultry coalitions specifically.
- **Universities and research institutions, including the Penn State Extension System:** These bodies may investigate and develop further opportunities and best practices for Carbon sequestration in existing agricultural operations. They may also partner with the state to conduct farmer trainings and surveys and provide lab-based soil testing and other highly valuable tools and resources.
- **Insurance companies:** The introduction of agricultural insurance requirements that consider climate risk could encourage adoption of conservation tillage and other sequestration-oriented agricultural practices.

Financial Considerations

The financial situation of many farming operations can make the adoption of no-till practices less attractive. However, the potential to reduce energy consumption, improve farmers' bottom lines, and build long-term operational resilience are highly valuable. Depending on the lens from which this strategy is viewed, financial considerations vary.

Participant Lens

While farmers will save money from decreased fuel consumption, there is significant capital cost associated with machinery replacements for no-till or air seeding practices that sequester carbon.

Individual farms can choose to voluntarily undertake agricultural energy efficiency measures. Federal incentives can help reduce financial barriers, but high upfront costs may be a barrier to adopt these measures. Especially because many farming operations operate in precarious financial situations, it may not be viable for farmers to make the initial investment in what may be a long-term cost saving improvement without additional support.

Implementer Lens

Farms that implement no-till management will experience costs associated with the transition, such as new equipment, administrative effort to plan cover cropping, and workforce training. As a result, farms may need to seek additional funding to support hiring and program management. PA DOA could establish a network of farms to share lessons learned or reduce costs and stress by offering technical assistance or pooling program resources.

Equity & Environmental Justice

Transitioning agricultural practices to less emissive machinery will require financial investment and personnel training wherever implemented. The state should take care to ensure that smaller farms, and minority and women-owned farms, have ready access to all tools and resources for no-till practices. Where possible, empower community farming coalitions and local leaders to encourage and facilitate the transition to reduced tillage. Additionally, by supporting farms and their sequestration potential, implementing this strategy aligns with the CAEJC action of preserving agricultural areas to function as carbon storage.

Action from the CAEJC Program that aligns with this strategy:

- **Preserve agricultural areas to function as carbon storage**

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 increased by climate change. BMPs may also improve the sustainability of agricultural practices to cope under changing climate conditions, reduce erosion, and improve soil health. Prioritizing equitable implementation of this strategy will allow these benefits of increased resilience to be realized in communities impacted by EJ issues.

L3. Land and Forest Management

Optimize carbon sequestration through sustainable forest and land management.

The land use, 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.

Pennsylvania's 6.9 million hectares (17 million acres) of forest land are estimated to sequester about 34 million $MTCO_2e$ annually. Conservation of these existing forests will be needed to maintain current sequestration levels. Several natural strategies were evaluated for their potential to increase the carbon sequestration of forestland in Pennsylvania, extending harvest cycles and reforestation showed the highest potential.[65,66,67] 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.

KEY METRICS

GHG emissions reductions:

2030: **1.14 $MMTCO_2e$**
2050: **1.16 $MMTCO_2e$**

Cost (or benefit) per ton $MTCO_2e$/reduced): **$16/$MTCO_2e$**

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; and
- **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.[65] An implementation period of 2025-2040 was assumed for these strategies. 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.

[65] 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: https://www.cell.com/one-earth/fulltext/S2590-3322(20)30603-5?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS2590332220306035%3Fshowall%3Dtrue.
[66] 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: https://www.science.org/doi/10.1126/sciadv.aat1869
[67] 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: https://www.climatehubs.usda.gov/sites/default/files/PA_ForestCarbon_MainReport.pdf.

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.

Many variables impact 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. Regenerating and growing new forests is also important in keeping sites productive. Young forests capture carbon quickly while conserving old growth forests and enhancing the growth of late-successional forests can increase carbon benefits. A mix of older forests and younger forests across the landscape is vital for forest health and habitat benefits. In some cases, extending harvest rotations of healthy, mature forests can enhance carbon storage. 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.

Resulting Impacts

Environmental

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

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.[65] 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.[68]

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)[69] and Oliver et al. (2014)[70] 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[71,72] but has not been extensively studied and represents a gap relevant to Pennsylvania forest management decisions.

RELATED FUNDING OPPORTUNITIES

USDA Grants and Partnership Programs

USDA offers grants and partnership opportunities to support climate-smart conservation efforts. The Conservation Innovation Grants program drives public and private innovation in natural resources conservation. The Regional Conservation Partnership Program partners work in collaboration with NRCS to help implement systems to conserve water, soil, and wildlife habitats while increasing climate resilience.

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68 Jacobson, M. 2021. Personal communication between Michael Jacobson and Pennsylvania State University.
69 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.
70 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.
71 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.
72 Miner, Reid A., et al. "Forest carbon accounting considerations in US bioenergy policy." *Journal of Forestry* 112.6 (2014): 591-606.

Social and Health

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. Additionally, forests provide resilience measures like reducing risks of flooding and impacts of storm surge. 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.

Implementation Considerations

The following actions could be taken as part of implementing this strategy:

- **Strategize opportunities for implementation.** Identify areas needing active or limited management, and areas where natural regeneration can occur.
- **Educate about and incentivize sustainable private land management**. Utilizing incentive and education programs for private landowners to participate in afforestation, no-till farming, and air seeding can scale the impact of this measure beyond programs on public land.
  - CEAP estimates the savings on fuel from no-till practices to be $17 per acre,[73] and encouraging these practices on private land can yield benefits for landowners.
  - Conducting outreach to private landowners about resources available to support forest stewardship, legacy planning, ecosystem restoration, and other beneficial practices can increase the
- Promote practices that diversify and enhance long-term forest health and therefore increase carbon sequestration and storage.
- Equip private and public landowners with the proper tools, information, and flexibility to incorporate climate change in management planning and implementation.
- 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.
- **Increase urban greenspace.** Provide incentives for shopping malls, office buildings, apartment buildings and other major urban centers in cities to establish and maintain greenspaces such as gardens, courtyards, and rooftop greenspaces. Focus on urban greening in

[73] Creech, Elizabeth. 2022. "Save Money on Fuel with No-Till Farming." https://www.farmers.gov/blog/save-money-on-fuel-with-no-till-farming#:~:text=By%20transitioning%20from%20continuous%20conventional,each%20year%20in%20fuel%20costs.

communities which have historically been deprived of trees and parks to increase public health, community investment, and felt connection to the environment. Encourage PA entities to apply for Urban and Community Forestry Grants funded by the IRA.

- Provide additional technical assistance and funding connections to organizations already supporting urban greenspace and food gardens and help them foster greater community connections.
- Increase forest cover by encouraging tree-planting initiatives and park restoration projects in public schools.
- Encourage the conversion of manicured lawns to meadow land to reduces the carbon footprint associated with maintenance through chemicals and equipment while also creating resilient landscapes that reduce flooding.

Partners and Participants

- **Indigenous groups in Pennsylvania**: Ancestral stewards of Pennsylvania's land and forests have long been excluded from conservation planning. The state should invite and empower holders of Traditional Ecological Knowledge for Pennsylvania's ecosystems to participate in land management and enable Tribal stewardship of land where possible.
- **Private landowners:** Private landowners (including individual homeowners, commercial enterprises, and the agriculture industry) can choose to participate in reforestation and restoration programs.
- **Conservation groups**: NGOs and local nonprofits with expertise in conservation and restoration (e.g., Northeast-Midwest State Foresters Alliance) can provide marketing, outreach, and education with Pennsylvania residents. They can also increase awareness of the importance of afforestation and grassland restoration, creating social momentum.
- **DCNR**: DCNR conserves Pennsylvania's natural resources for present and future generations which includes forests, parks, and recreational opportunities like trails. DCNR works with private landowners, municipalities, nonprofits, and federal and state landowners to strategically manage land for optimal carbon sequestration and resilience.
- **Federal Land Use and Forestry Agencies**: The National Park Service, US Forest Service, and Fish and Wildlife Service, which oversee 80%, 10%, and 10% of federally owned land, respectively may provide resources, oversight, and technical assistance to forestry and restoration projects.
- **Interstate partnerships**: Organizations like the Appalachian Regional Reforestation Initiative may provide technical guidance on restoration practices.

- **PA Department of Agriculture**: PDA provides resources and guidance through the Pennsylvania Hardwoods Development Council and works directly with industry stakeholders. Additionally, PDA provides resources through the PA State Conservation Commission for forestry and water quality BMPs focused on the utilization of trees.
- **Community land trusts**: Community land trusts own and manage land to provide long-term, affordable housing to residents renting on the land owned. As such they can play a role in land stewardship through sustainable land management to benefit people and the environment.

Financial Considerations

Depending on the lens from which this strategy is viewed, financial considerations vary.

Participant Lens

- **Voluntary measures:** Private landowners may choose to voluntarily implement initiatives to increase natural sequestration. They may see negative opportunity cost to reforesting their land.
- **Programmatic:** The state will need funding for grants or other economic incentives to reforest and establish emissions-reducing, carbon-sequestering land management practices. Ensure abundant resources are readily available for any party interested.
- **Required from legislation:** Incentives, subsidies, or tax breaks for the afforestation or other conservation-oriented management of private land will require funding from the State.

Implementer Lens

There is an opportunity cost to reforesting land. Additionally, abandoned mine lands require extensive site preparation, and legacy mine lands have additional costs from deep tilling of heavily compacted soil and control of existing vegetation.

Equity & Environmental Justice

Given the linkages of ecological, economic, and social systems, to ensure that local and nonlocal needs are met, management decisions and policies should be guided by expert science as well as local and Indigenous knowledge through community participation. The integration of Traditional Ecological Knowledge and encouragement of Tribal involvement in land management programs will both empower

Actions from the CAEJC Program that align with this strategy:

- Substantiate how natural environmental strategies will impact micro-local communities.
- Increase public ecosystem and conservation efforts on public lands.
- Mitigate existing sites and sources of air and water pollution.

historically excluded Indigenous communities and knowledge holders and bolster the efficacy and holistic reach of land management and restoration programs. Working with tribes will help substantiate how natural strategies can impact micro-local communities, which is also a key CAEJC-identified action.

An emphasis on locality and orientation to community in restoration projects will also be highly valuable for fostering long-term connections to the land, and empowering local communities to be stewards.

Working with communities impacted by EJ issues to determine opportunities for beneficial implementation can result in GHG reductions as well as increased resilience in vulnerable communities. Depending on where reforestation, afforestation and harvest cycle extension practices occur, there may be an opportunity for these practices to provide benefits, such as reducing urban heat island effects, or improving ecosystem connectivity or reducing runoff or flood risks. By prioritizing equity, Pennsylvania can target these benefits to communities that disproportionately experience these effects of climate change.

Implementing afforestation practices on abandoned coal mines may have a positive impact on previously highly industrialized communities. This could include benefit public health in communities that previously experienced a high volume of criteria pollutant emissions. Afforestation efforts and the associated public health benefits also align directly with CAEJC-identified actions related to ecosystem conservation and pollution mitigation.

Cross Cutting Technologies

With increased incentives to reduce emissions, a growing number of technologies are being explored to prevent the release of carbon emissions into the atmosphere by capturing them when they are generated. Once captured, the CO_2 can then be utilized in a variety of ways (e.g., for commercial products such as carbonated drinks or concrete) or injected deep underground where it can be stored.

While most commonly used at large power plants, refineries, and industrial facilities, CCUS is not yet ubiquitous, and work still needs to be done to reduce the costs of these technologies and improve capture rates in certain circumstances.[74] Though not modeled in this section, additional technologies are being explored in carbon dioxide removal that seek to directly remove CO_2 that is already in the atmosphere; two key pathways in this space that share a technological foundation with CCUS include bioenergy with CCS and direct air CCS.[74]

Additionally, there is increased interest in the production of clean hydrogen fuel in the Commonwealth. Natural gas can be used to generate hydrogen fuel through a process known as steam methane reforming, which can be paired with CCUS to reduce emissions. Both the Appalachian Hydrogen Hub and the Mid-Atlantic Hydrogen Hub have received funding from the US DOE to increase the production, distribution, and use of hydrogen in varying areas of Pennsylvania. As a fuel, hydrogen can be generated through multiple processes. Each process may result in differing emissions, some significant and others more minimal. In the past, hydrogen has been referred to by a specific color to clarify how it was produced. Common colors include:

- **Pink Hydrogen**: produced from nuclear energy
- **Blue Hydrogen**: produced from natural gas with CCUS
- **Green Hydrogen**: produced from clean electricity (i.e., solar or wind)

However, as most current and planned hydrogen projects use a combination of feedstocks, there has been a movement to move away from color classifications and instead categorize on carbon intensity of production.

To reflect these technological trends, two strategies were modeled for this CAP.

Table 17. Cross Cutting Technologies sector GHG reduction strategies and associated reductions ($MMTCO_2e$)

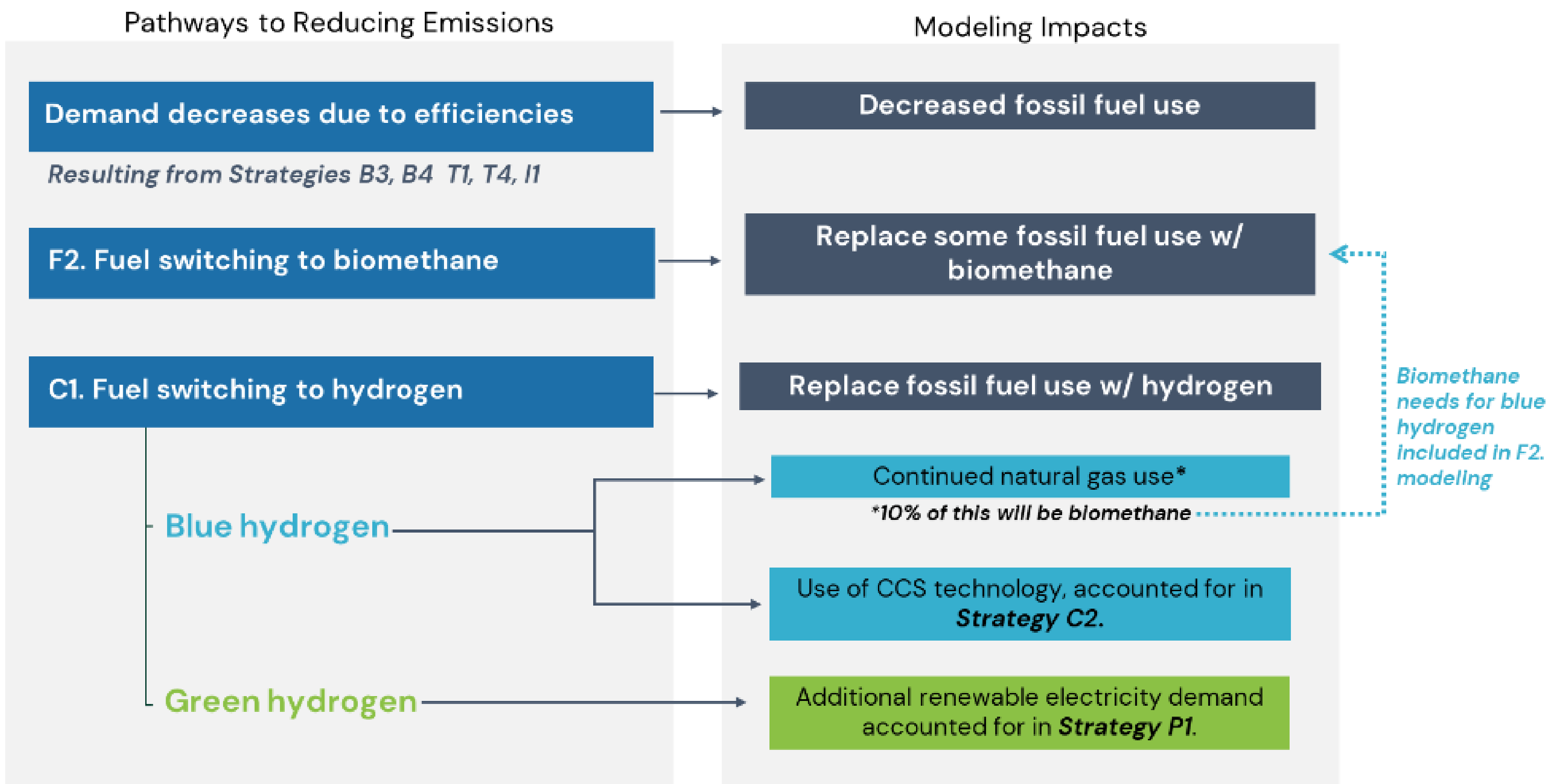
GHG Reduction Strategy	2030	2050
C1. Hydrogen Fuel	0.46	9.41
C2. Carbon Capture and Storage	0.02	2.80

[74] "What Is Carbon Capture, Usage and Storage (CCUS) and What Role Can It Play in Tackling Climate Change?" Grantham Research Institute. Accessed October 31, 2023. https://www.lse.ac.uk/granthaminstitute/explainers/what-is-carbon-capture-and-storage-and-what-role-can-it-play-in-tackling-climate-change/.

Capturing and storing carbon in the Commonwealth was modeled using a least-cost model for the power sector to deploy point source carbon capture. Through the tool, a range of carbon producing electrical plants would be retrofitted with carbon capture equipment. Hydrogen was modeled to replace a portion of natural gas demand across sectors (for power generation, medium- and heavy-duty transport, and for hydrogen blending for building energy needs), with that proportion estimated to increase over time as more hydrogen production comes online. Both blue and green hydrogen were considered.

As hydrogen and CCUS cut across multiple sectors, the emissions savings identified will be realized across sectors. Additionally, due

Figure 23. Cross Cutting Technology Interconnections of Reducing Emissions from Fossil Fuels



to their cross cutting nature, modeling of these strategies has interactions with other strategies. For example, blue hydrogen requires both natural gas and CCUS technology to be produced, with biomethane being about 10% of natural gas inputs for many producers. By using biomethane, producers achieve carbon neutral production, offsetting the small portion of production emissions that cannot be captured using CCUS technologies. This and other interconnections are shown in Figure 23.

Equity in the Cross Cutting Technologies Sector

Accessibility: Cross cutting technologies can be expensive, so emphasizing and supporting affordability for those areas where they are most needed should be considered.

Advocacy: Particular attention should be placed on how strategies will impact workers and those others who work, live, and go to school in proximity to proposed cross cutting technology infrastructure.

Accountability: To remain accountable in this area means understanding the social costs of carbon and being transparent about the carbon intensity of hydrogen production.

C1. Hydrogen Fuels

Expand use and generation of hydrogen fuels.

This strategy includes the dedicated use of hydrogen as well as blending of hydrogen into existing gas systems, pipelines, and operations. Dedicated use of hydrogen could take place in hubs of industrial operations or other use cases where the fuel is either burned or run through a fuel cell to generate needed power. Hydrogen blending involves injecting hydrogen into existing pipelines, heating systems, and power systems to replace a percentage of the natural gas currently being used. Low levels of hydrogen blending are feasible without retrofit projects of distribution systems.[75] When compared to burning natural gas alone, hydrogen blending results in reduced GHG emissions.

Hydrogen fuel can be used in a variety of applications in sectors that are traditionally hard to decarbonize including steelmaking, aviation, and heavy-duty trucking. When produced using carbon-free energy sources, like wind or solar power, hydrogen is zero carbon fuel that can reduce emissions when replacing fossil fuels. Where renewable energy is not available, hydrogen can be produced with natural gas and paired with CCUS technologies to reduce the net emissions resulting from production.

KEY METRICS

GHG emissions reductions:

2030: **0.46 MMTCO$_2$e**
2050: **9.41 MMTCO$_2$e**

Cost (or benefit) per ton MTCO$_2$e/reduced): **$433/MTCO$_2$e**

Hydrogen production is expected to increase in Pennsylvania, particularly through the Appalachian Regional Clean Hydrogen Hub (ARCH2) and the Mid-Atlantic Clean Hydrogen Hub (MACH2) efforts, two projects that were awarded funding by the DOE, that will provide a total of almost $1.7 billion to expand production and use of hydrogen throughout Pennsylvania and other participating hub states.

Resulting Impacts

Environmental

To maximize emissions reductions, hydrogen must be produced with the lowest carbon intensities possible, through either electrolysis using zero carbon electricity or through adding CCUS technologies to other production processes, such as steam methane reforming of natural gas. Steam methane reforming is currently the most common method for producing hydrogen in the United States today, and most hydrogen in the United States is considered gray hydrogen.

Displacing fossil natural gas through the use of hydrogen blending will lead to a decline in net emissions of GHGs such as CO_2 and CH_4.

[75] Kevin Topolski et al., "Hydrogen Blending into Natural Gas Pipeline Infrastructure: Review of the State of Technology." https://www.nrel.gov/docs/fy23osti/81704.pdf.

Economic

Expansion of hydrogen fuel production is anticipated to lead to significant job creation, particularly in energy communities, including Pennsylvania's legacy coal communities. Jobs are anticipated in a variety of fields including construction such as those for infrastructure projects such as pipeline development.

Additional economywide impacts are anticipated depending on the level of hydrogen penetration in the power and industrial sectors along with a level of interest in hydrogen technologies by other potential end users throughout the state. Where replacing fossil fuels, hydrogen expansion could lead to job reductions in those industries.

Social and Health

While hydrogen fuels can reduce net GHG emissions and the emissions of other air pollutants such as VOCs, the combustion of hydrogen fuel, when done in the presence of air, can still lead to generation of nitrous oxides,[76] which can contribute to community air pollution and negative health impacts. When used in fuel cells, hydrogen does not generate these nitrous oxides, leading to air quality benefits.

Implementation Considerations

The federal government, through funding in the IRA and IIJA and through numerous DOE programs, is playing a significant role in the development of hydrogen technologies and expanding use of hydrogen as a fuel to support decarbonization. The following actions could be taken as part of implementing this strategy:

- Verify that hydrogen is produced and used in a way that will reduce emissions. This may include updating regulations/aligning with emerging regulations on hydrogen safety; certification, and methodology/ verification of carbon intensity, etc.
- Incentivize the offtake of hydrogen into priority sectors, including heavy-duty transportation (i.e., aircraft, ocean-going vessels, hydrogen powered forklifts, and other offroad vehicles) and industries that cannot or should not be electrified (i.e., cement production, steel and aluminum smelting, and chemical refining).
- Streamline and standardize permitting for hydrogen production facilities and offtake infrastructure like pipelines and fueling stations.

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[76] Alastair C. Lewis. "Optimising Air Quality Co-Benefits in a Hydrogen Economy: A Case for Hydrogen-Specific Standards for NOx Emissions." *Environmental Science: Atmospheres* 1, no. 5 (July 22, 2021): 201-7. https://pubs.rsc.org/en/content/articlelanding/2021/ea/d1ea00037c.

- Scale the use of new technologies through education of interested parties. By engaging with interested parties (especially end users) to educate them on the potential applications and benefits of using hydrogen fuels.
- Incorporate hydrogen considerations into zoning and building code updates and provide training for local code officials to expedite the permitting of new hydrogen projects and infrastructure.
- Expand hydrogen transport and refueling infrastructure through incentives.

Hydrogen may require new or retrofitted equipment so that it can be used as a fuel, and 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. Additionally, though federal tax credit 45V will make the production of hydrogen more economically viable in the short term, the market will need to become cost effective/stand on its own, following the phaseout of tax credits.

Partners and Participants

- **MACH2 and ARCH2 hydrogen hubs:** Will play a role by coordinating with hydrogen producers, consumers, and transporters.
- **Consumers:** Most end users in the hydrogen economy will be in hard-to-electrify sectors like industrial and power sectors, while transport uses will be from heavy-duty trucking. Local governments may end up using hydrogen as well via the purchase and use of public transport buses, garbage trucks, and other heavy-duty maintenance vehicles.
- **Industry (Producers and Transporters):** Industry will manufacture new technologies to enable the use of hydrogen fuels such as fuel cells, electrolyzer producers, refueling stations for hydrogen powered vehicles, pipelines, and more. Industry will also develop hydrogen delivery infrastructure such as pipelines, liquefaction plants, liquid tankers, dispensers, and more.
- **Inspectors and regulators:** Inspectors and regulators will play a role reviewing H_2 infrastructure, detecting leaks, and more.

Financial Considerations

Depending on the lens from which this strategy is viewed, financial considerations vary.

RELATED FUNDING OPPORTUNITIES

Regional Clean Hydrogen Hubs

Pennsylvania has secured funding through two (2) regional clean hydrogen hub applications, the only state to have more than one Pennsylvania applicants have secured funding through two (2) regional clean hydrogen hub applications, the only state to have more than one (1). $1.7 billion has been awarded to expand the production and use of hydrogen in the region across the MACH2 and ARCH2 hubs.

Participant Lens

Most participants in the hydrogen economy will be in the industrial and power sectors, while transport uses will be from heavy-duty trucking, and more. The costs to participants will vary depending on the specific technologies developed. Costs will also vary as the prevalence of the technology increases. Both lessons learned over time and research and development may least to a decrease in the cost barriers of hydrogen technologies through increased efficiency.

- **Voluntary measures:** With federal tax credit 45V, hydrogen production will be able to be more cost competitive as a fuel, though upfront costs to scale up infrastructure and hydrogen supply will be incurred. Additionally, while tax credits are available, end users of hydrogen will see lower fuel costs, though they will likely experience upfront capital costs for the purchase of new hydrogen powered equipment. Current natural gas users would be able to blend hydrogen into their existing pipelines with minor infrastructure upgrade costs.
- **Required from legislation:** Compliance with specific production rules from the IRS is required to be eligible for tax credits, meaning that hydrogen producers and regulators will also see costs associated with reporting and compliance.

Implementer Lens

Support will be needed for developing infrastructure. Federal funding has been made available and can help reduce the cost barriers of developing new hydrogen infrastructure. However, additional funding may be required to support the full deployment of this technology. Additionally, training inspectors and regulators to work with new technologies may require additional funding.

Equity & Environmental Justice

The development of hydrogen technology may result in the creation of jobs. Pennsylvania can work with the ARCH2 and MACH2 clean energy hubs to facilitate the equitable distribution of these jobs.[77] Additionally, when evaluating which sectors or uses of hydrogen are most viable, costs should be considered, to emphasize uses that are most cost effective and do not place undue financial or tax burden on communities facing EJ issues.

[77] "Governor Josh Shapiro: Pennsylvania the Only State to Secure Two Regional Clean Hydrogen Hub Projects." PA Department of Community & Economic Development. October 13, 2023. https://dced.pa.gov/newsroom/governor-josh-shapiro-pennsylvania-the-only-state-to-secure-two-regional-clean-hydrogen-hub-projects/.

C2. Carbon Capture, Utilization, and Storage

Deploy and continue to pursue new carbon capture technologies for power and industrial systems.

One of the primary pathways to decarbonize industrial processes is the use of carbon capture technology. CCUS can also be used to capture carbon in the from coal- or gas-fired electricity generating units in the power sector or from large industrial plants. This strategy aims to support decarbonization in hard to abate sectors, such as industry, where electrification and efficiency are insufficient to achieve deep decarbonization, and in the power sector, where CCUS can provide reliability for a net zero grid (P1) by helping fossil fuel-powered generating plants continue operating. Metrics provided in this section include CCUS from industrial applications, and metrics associated with CCUS for the power sector are included in the net zero grid (P1) strategy.

KEY METRICS

GHG emissions:

2030: **0.02 MMTCO$_2$e**

2050: **2.80 MMTCO2$_e$**

Cost (or benefit) per ton MTCO$_2$e/reduced): $431.78 /MTCO$_2$e

Resulting Impacts

Environmental

Most CCUS technology in development aims to capture 90-99% of CO_2 emissions, but CCUS technology does not alleviate or capture all GHGs or harmful air pollutants. Uncaptured emissions of CO_2 and other GHGs, such as CH4 and N2O, associated with the combustion of fossil fuels will still be present. In addition to GHGs, fossil fuel combustion also produces criteria pollutant emissions such as NOx, SOx, PM2.5, and VOCs that are ground-level ozone precursors.

Economic

Investments in CCUS are expected to spur job growth from the construction of the systems on power plants or industrial sites. Depending on how the captured carbon is used, additional economic benefits could arise if it is used in a product. CCUS will result in increased energy costs from power plants installing such capture technology. Investment in scaling up production of CCUS can help reduce the associated costs.

Social and Health

Capturing emissions would lead to reduced GHG pollution, but other criteria pollutants would continue to be emitted impacting health care costs, and health implications, while also potentially impacting physical comfort and individual and community productivity. Most of the anticipated CCUS applications are intended to be retrofits to existing power and industrial plants.

Implementation Considerations

The federal government, through funding in the BIL, ARRA, IIJA, and IRA, is playing a significant role in the development of CCS technologies. The following actions could be taken as part of implementing this strategy:

- Track progress on research and development into new CCUS technologies and their applications to the context of Pennsylvania.
- Put in place enabling policy and regulation to accelerate infrastructure deployment of CCUS infrastructure including CCUS hubs, regulation & permitting, supply incentives, demand-side procurement and incentives, workforce education and training.
- Collaborate with interested parties to scale and communicate the benefits of CCUS technology action. It will be necessary to work with private sector partners to identify opportunities for the beneficial use of CCUS technology.

Partners and Participants

Key partners include:

- **State government:** Coordination between Pennsylvania agencies can centralize knowledge and processes relevant to deploying CCUS. For example, the CCUS Interagency Work Group is a state-level collaboration between DCNR, DEP, DCED, and PA PUC to coordinate opportunities for the application of CCUS. The Work Group also provides industry and interested parties with streamlined access to information on technical, regulatory, and economic considerations.

RELATED FUNDING OPPORTUNITIES

Expansion of 45Q Tax Credits

The IIJA significantly increased tax credits for carbon use and storage under Section 45Q of the Internal Revenue Code. The expansion now includes all carbon oxides not just CO_2. The expansion also sets a deadline to start construction of 2026 with a 12-year claim period. The original cap of 75 million tons was also removed. This credit is between $10 and $36 per metric ton depending on when the equipment was put in place and how the carbon is captured (with direct air capture receiving the largest credit).

- **Federal government:** Can support the development of new technologies, update regulations, and incentivize investments. The federal government can enable pilot projects by updating regulations, or through permitting once research demonstrates the feasibility of applications of CCUS technologies.
- **Industry:** Members of various industrial sectors such as power generation, iron and steel, chemical and petrochemical, cement, and others will play a role by participating in retrofits to their facilities.

Financial Considerations

Depending on the lens from which this strategy is viewed, financial considerations vary.

Participant Lens

The costs to participants will vary depending on the specific technologies developed and financing mechanisms adopted. Costs will also vary as the prevalence of the technology increases. Both lessons learned over time and research and development may least to a decrease in the cost barriers of CCUS technologies through increased efficiency.

Implementer Lens

As new CCUS technologies develop, there are significant costs to participants associated with deploying these technologies. Federal incentives already exist and can help reduce financial barriers to completing projects.

There may be costs associated with hiring and training employees to build, operate, and maintain the necessary infrastructure.

Equity & Environmental Justice

There is potential for job creation due to the expansion of CCUS technology. Building, operating, and maintaining the infrastructure needed to deploy the technology will require qualified staff. To prioritize equitable implementation, Pennsylvania can prioritize hiring a local workforce. By deploying CCUS technologies, fenceline communities are unlikely to see benefits from increased efficiency and lower localized air pollution, since CCUS does not capture harmful air pollutants. Poor public health outcomes in highly industrialized communities could continue and the measure would not provide any air pollution mitigation, a priority of communities facing EJ issues, as identified by outreach conducted in the CAEJC program.

Air Quality Health Impacts and Modeling Results

This section describes the impacts to health from changes in air quality by type of pollutants. Most of the proposed GHG emission reduction strategies would result in a reduction of energy and fuel use for electricity generation, buildings, industry, or vehicles. Ambient (outdoor) air quality improvements would result from less fossil fuel (natural gas, oil, coal, propane) combustion, as well as a reduction in upstream emissions (associated with fuel extraction and transport). The pollutant of greatest concern with natural gas and gasoline combustion is nitrogen oxides (NO_x). In addition to NO_x, the combustion of coal, oil, and diesel results in the emissions of fine particulate matter ($PM_{2.5}$) and sulfur dioxide (SO_2). In addition to improving ambient air quality, some of the proposed building sector strategies would also improve indoor air quality – eliminating or reducing the emissions of combustion air pollutants indoors, for example with electric stoves and other appliances.

- NO_x emissions are precursors to the formation of ground-level ozone (smog), a health risk, particularly to people with asthma, children, older adults, people who are active outdoors, and outdoor workers. Ozone exposure can cause coughing and sore or scratchy throat, make it more difficult to breathe deeply and cause pain when taking a deep breath, inflame and damage the airways, make the lungs more susceptible to infection, aggravate lung diseases such as asthma, emphysema, and chronic bronchitis, and increase the frequency of asthma attacks.[78]
- $PM_{2.5}$ consists of microscopic solids or liquid droplets that can be inhaled and cause serious health problems. Some particles less than ten micrometers in diameter (PM_{10}) can get deep into the lungs and even into the bloodstream. Of these, particles less than 2.5 micrometers in diameter, also known as fine particulates or $PM_{2.5,}$ pose the greatest risk to health. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including premature death in people with heart or lung disease; nonfatal heart attacks; irregular heartbeat; aggravated asthma; decreased lung function; and increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing.[79]
- The largest source of SO_2 in the atmosphere is the burning of coal by power plants and other industrial facilities. Short-term exposures to SO_2 can harm the human respiratory system and make breathing difficult. People with asthma, particularly children, are sensitive to these effects of SO_2.

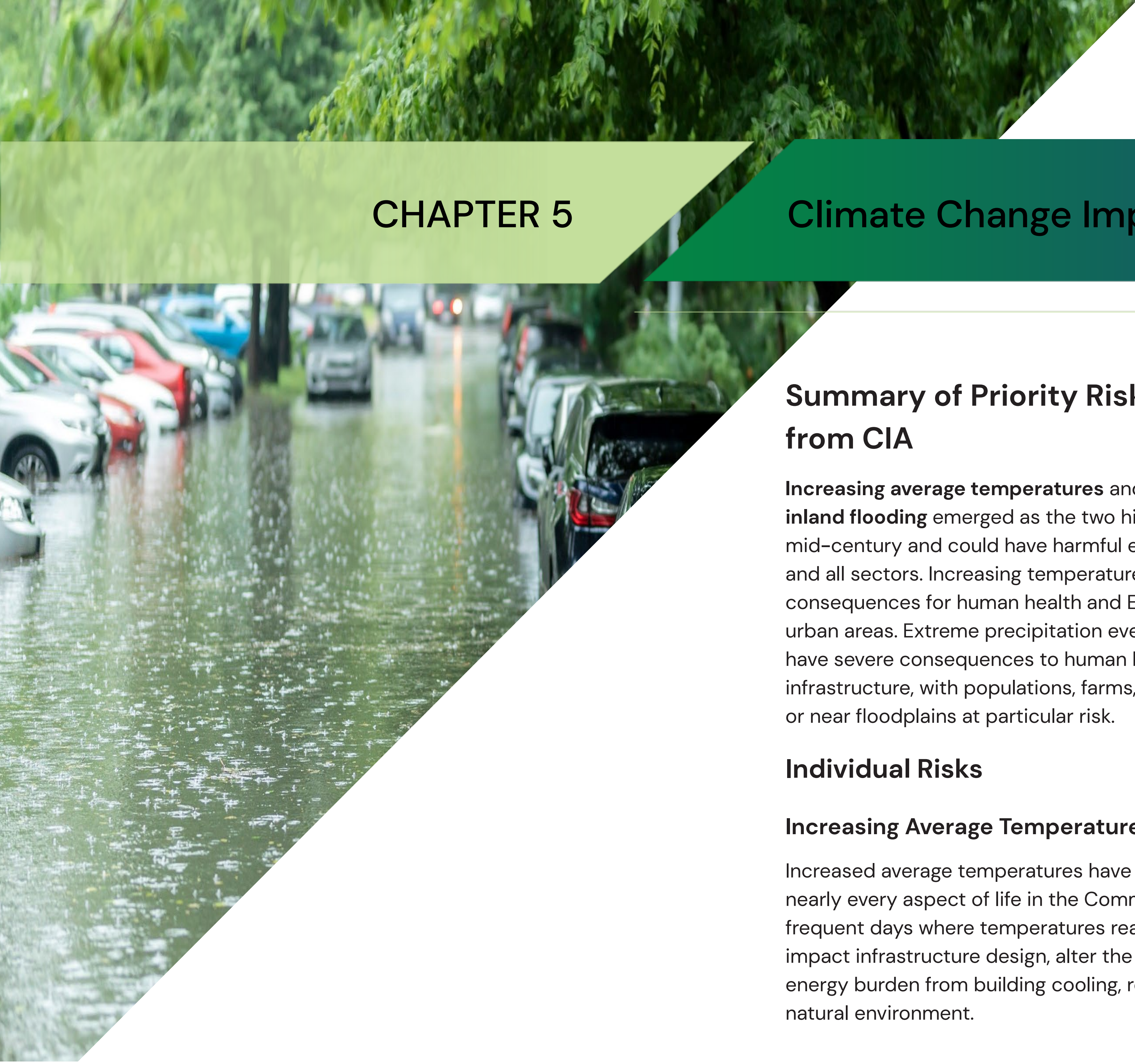
A summary of strategy reductions in air pollution for select measures can be found in Table 18. For some strategies, air quality impacts change over the life of the modeled implementation as technologies change. Analysis excludes power sector emissions (electricity) since air quality changes are dependent on the change in when electricity is being used and modeling did not provide that information.

[78] US EPA, OAR. 2015. "Health Effects of Ozone Pollution." Overviews and Factsheets. https://www.epa.gov/ground-level-ozone-pollution/health-effects-ozone-pollution.

[79] US EPA, OAR. 2016. "Health and Environmental Effects of Particulate Matter (PM)." Overviews and Factsheets. https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm.

Table 18. Total Emissions Reduction, $MTCO_2e$ (2025-2050)

Strategy	NOx	SOx	PM
B1. Building Codes	162	3,474	103
B3. Gas Efficiency in Buildings	73	11,475	928
B4. Building Electrification	5,548	107,233	8,629
I1. Industrial Efficiency	3,962	115,500	6,598
I2. Gas, Fuel, and Process Decarbonization	14,118	130,859	8,455
T1. Transit and Multimodal Improvements	228	8,246	487
T2. Light-Duty Vehicle Electrification	108	17,628	190
T3. Zero Carbon Medium- and Heavy-duty Vehicles	248	43,959	381
C1. Hydrogen Fuels	1,551	361,835	19,642
L2. Agriculture Best Practice: Carbon Sequestration	0.6	31	2
Total	**26,000**	**800,242**	**45,415**



CHAPTER 5 Climate Change Impacts

Summary of Priority Risks and Impacts from CIA

Increasing average temperatures and **heavy precipitation and inland flooding** emerged as the two highest-risk hazards by mid-century and could have harmful effects across the entire state and all sectors. Increasing temperatures have the highest consequences for human health and EJ and equity, especially in urban areas. Extreme precipitation events and flooding could also have severe consequences to human health, agriculture, and built infrastructure, with populations, farms, and infrastructure located in or near floodplains at particular risk.

Individual Risks

Increasing Average Temperatures

Increased average temperatures have the potential to impact nearly every aspect of life in the Commonwealth, with more frequent days where temperatures reach at least 90°F. This will impact infrastructure design, alter the growing season, increase energy burden from building cooling, recreational activities, and the natural environment.

Heavy Precipitation and Inland Flooding

Based on the available modeling, in the coming century the Commonwealth will see an increase in average annual precipitation and extreme precipitation events. Flooding from heavy precipitation events can affect infrastructure, human health, and agriculture through damaging events like landslides and sinkholes, or over a period of time lead to increased infrastructure deterioration. Additionally, low-wealth and minoritized communities are more commonly located in floodplains, putting them at a high risk of displacement and other negative impacts.

Heat Waves

Heat waves similar to those experienced in the summer of 2023 will be more common as average temperatures increase. These will create health (i.e., heat stress) and economic impacts (i.e., energy burden) 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 are particularly acute in areas subject to the urban heat island effect.

Landslides and Sinkholes

Projections indicate that an increase in the frequency and intensity of severe precipitation events could increase landslide risk. Landslides and sinkholes are already serious hazards in the Commonwealth that affect transportation and energy networks and buildings, creating serious health and safety concerns. As the frequency and intensity increase, so do the risks and impacts.

Sea Level Rise and Coastal Changes

Areas of Pennsylvania along the Delaware estuary will experience the effects of coastal change and sea level rise. This will lead to an increase in frequency and intensity of storm surge flooding which can lead to damage to property and infrastructure such as closure of interstates.

Coastal changes and variability along the Lake Erie coast will lead to reduced water quality and increased erosion. This can result in algal blooms and greater bluff instability.

Severe Tropical and Extra-Tropical Cyclones

Extreme weather events will continue to have severe impacts on Pennsylvania as climate change increases the intensity of extreme weather events. This can result in danger and increased economic impacts with the Commonwealth already seeing a rise in billion-dollar disaster events, such as Hurricanes Beryl and Debby in 2024 (Pennsylvania Billion-Dollar Weather and Climate Events).

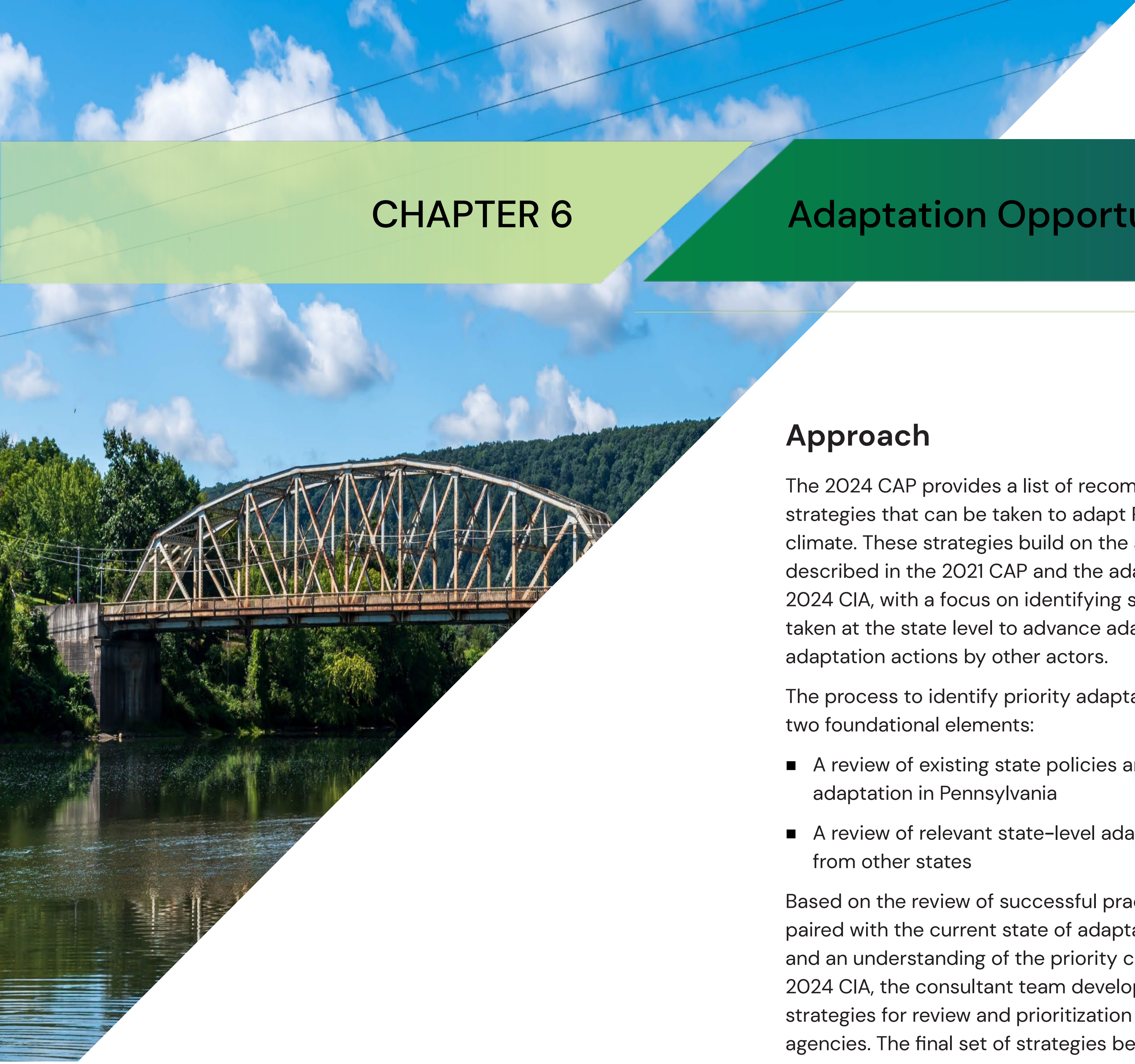
Overall Risks

Climate risks and impacts in Pennsylvania are likely to be severe stemming from infrastructure disruptions, higher risks to public health, economic impacts, and other changes. Taking action to mitigate climate change through reduced emissions can help reduce the changes while taking adaptation measures also present an opportunity for the Commonwealth to prepare for these impacts to strengthen its economy, reduce inequalities, and build resilience.

The CIA identifies the following as top priority areas for climate adaptation:

- Reduce extreme heat risks to human health, particularly for vulnerable populations
- Support key sectors in the transition to a warmer climate, including agriculture, recreation and tourism, and forests, ecosystems, and wildlife
- Reduce flood risks to infrastructure and communities and increase their ability to cope and recover from the impacts of flood events
- Increase utility resilience to climate hazards with special consideration of outage impacts to vulnerable populations
- Help low-income households cope with potential increased energy burden
- Enhance tropical storm and landslide risk mitigation

The next chapter goes in depth on the adaptation opportunities that the Commonwealth can take advantage of to reduce the risks and impacts discussed here. These adaptation opportunities are complementary to the mitigation activities in the CAP.



CHAPTER 6 Adaptation Opportunities

Approach

The 2024 CAP provides a list of recommended adaptation strategies that can be taken to adapt Pennsylvania to a changing climate. These strategies build on the adaptation pathways described in the 2021 CAP and the adaptation priorities from the 2024 CIA, with a focus on identifying specific strategies that can be taken at the state level to advance adaptation and enable adaptation actions by other actors.

The process to identify priority adaptation strategies included two foundational elements:

- A review of existing state policies and activities related to adaptation in Pennsylvania
- A review of relevant state-level adaptation policies and activities from other states

Based on the review of successful practices from other states, paired with the current state of adaptation actions in Pennsylvania and an understanding of the priority climate risks from the 2024 CIA, the consultant team developed a set of potential strategies for review and prioritization in conjunction with state agencies. The final set of strategies below are based on priorities from state agencies.

Strategy costs are indicative of the level of resources required to execute the strategy and are evaluated based on the following scale:

- $ – implementation can occur with limited use of new funds and can rely on operational changes and existing programs.
- $$ – Implementation can occur with use of existing grants, allocations, funding, and limited to no new capital allocations.
- $$$ – Implementation requires extensive allocations, large grants, and/or dedicated funding streams.

Strategies may include a range of costs, indicating that the level of resources required may vary depending on the level of implementation.

Adaptation strategies

Table 19 lists the final set of priority adaptation strategies for the CAP. Additional detail on each is provided in the table:

Table 19. Adaptation Strategies

Adaptation Strategy	Hazard(s) Addressed
A1. State Agency Coordination: Coordinate across agencies and jurisdictions on climate adaptation and resilience efforts. Designate a chief resilience officer or other champion that reports to the state, local, or municipal executive to lead these efforts.	Cross Cutting
A2. Local Adaptation Program: Incentivize or otherwise promote local municipal and regional climate change vulnerability assessments and adaptation plans and establish grant programs or financing mechanisms to fund associated adaptation projects that build local resilience.	Cross Cutting
A3. Nature-based Solutions: Promote the use of green infrastructure and nature-based solutions (including urban trees), to mitigate storm water impacts and urban heat island effects and incentivize its use in new developments through existing state economic development programs and brownfield redevelopment programs.	Flooding; Extreme Heat; Power Outages
A4. Utility Climate Risk Analysis: Encourage regulatory bodies to require climate risk analysis for water supply and energy utilities, identifying specific risks, timeframes and locations of impact, resilience actions to	Cross Cutting

mitigate identified risks, as well as any gaps needing additional research.	
A5. Enhanced Workplace Health and Safety Protections: Promote state and local adoption of legal protections, requirements, and best practices for workplace health and safety (such as expanded PPE use, multi-lingual heat safety guides, and additional protections for vulnerable groups) to protect workers from exposure to dangerous heat conditions.	Flooding; Extreme Heat
A6. Evaluation of Equity Impacts: Require the evaluation of EJ areas and other historically disadvantaged and marginalized groups when evaluating climate risk and adaptation strategies, in order to ensure equitable distribution of risks and benefits.	Cross Cutting
A7. Climate Resilient Design Guidelines: Adopt guidance to incorporate climate projections into built infrastructure design (such as requiring flood protection measures through building codes based on the Federal Flood Risk Management Standard).	Flooding
A8. Enhanced Emergency Management: Expand existing extreme weather emergency response management to consider the increased frequency and severity of extreme weather events due to climate change, through measures that include but are not limited to enhanced early warning systems, additional staffing and equipment, public outreach, and additional training.	Extreme Heat; Flooding;
A9. Property Risk Disclosure: Adopt and enforce requirements for property owners to disclose information about a building's propensity to flood when renting or selling the property and include information on whether mold remediation has been or will need to be conducted.	Extreme Heat; Flooding; Tropical Storms
A10. Health Impacts Tracking: Encourage public health agencies to track and analyze health data to better understand climate-related health impacts (including heat, flooding, vector-borne diseases, and air quality impacts from wildfires or an increase in ground-level ozone) and take steps to address these impacts, giving particular consideration to inequitably distributed impacts.	Extreme Heat; Flooding; Tropical Storms

A1. State Agency Coordination

Coordinate across agencies and jurisdictions on climate adaptation and resilience efforts. Designate a chief resilience officer (CRO) or other champion that reports to the state, local, or municipal executive to lead these efforts.

Collaboration across agencies and jurisdictions will be crucial to build adaptive and resilient systems.

KEY METRICS

Climate hazard risks reduced: All

Benefits: Fosters synergy across state and local entities in tackling climate risks and adaptation needs.

Costs: $

Emissions impacts: positive or neutral

Resulting Impacts

Climate changes are complex, impacting social, environmental, and infrastructural systems locally and regionally across jurisdictions. Collaboration between Pennsylvania's local and state-level agencies can establish strong climate resilience networks to tackle risks that are inflicting damage and causing losses across communities and sectors. These networks can create opportunities to share information across agencies on projects and programs that have created positive outcomes and lessons learned from responding to past climate events.

Establishing a champion to lead these efforts is important to ensure connections are made wherever necessary and actions are targeted in the most vulnerable and impacted areas. With climate change requiring new collaboration across state and local governments, many state agencies already have climate adaptation champions working within them. State agencies should be supported in building off existing climate adaptation work to lead new resilience initiative.

A CRO can support cross-agency coordination by acting as a climate resilience and adaptation knowledge base, helping agencies and jurisdictions leverage available state resources to address climate risks. By working directly with collaborating state and local entities, the CRO can help report on additional resources needed to support adaptation projects across the state. The multifaceted nature of the CRO's role can help improve the state's understanding of knowledge gaps.

The risks to public health and safety brought by climate change require the long-term, repeated collaboration of many state agencies and jurisdiction to further local and regional climate resilience. Individual agencies may need additional training resources to prepare for future collaboration. These capacity building initiatives will also help strengthen multi-agency collaborative efforts outside of climate partnerships and projects.

Equity Implications

The impacts of climate change are felt locally as well as regionally, and can affect Tribal, local, and private resources. The designated CRO should have expertise in EJ and a stated mission to uplift collaborative efforts to address EJ issues and foster equity. The prioritization of EJ ensures a holistic approach, allowing all sectors and issues to be considered while planning to address adaptation needs.

Implementation Considerations

Local Partnerships

Local jurisdictions can also be supported in appointing their own CROs to provide in-house expertise for municipal entities. Locally, CROs can help lead stakeholder engagement and promote synergy; enhancing internal collaboration can make it easier to realize resilience co-benefits that span issue areas.[80]

In 2015, Pittsburgh appointed a CRO and joined the 100 Resilient Cities network. The 100 Resilient Cities program provides in-network cities with guidance to establish a CRO, develop strategies and access new solutions and partnerships in various sectors. Improvements planned throughout Pittsburgh include affordable housing, Pre-K for all, and other initiatives estimated at $3 billion in funding over 12 years.

Legal and Financial Considerations

State regulatory action may also be needed to establish additional needs and identify financial pathways and partnerships to support the appointment and long-term operation of local and state-level CROs. For example, through New Jersey's EO No. 89 in 2019, the state's Interagency Council on Climate Resilience was established to support the implementation of New Jersey Statewide Climate Change Resilience Strategy.[81] The Council includes various New Jersey state and regional agencies and is led by the CRO, who provides technical guidance and support to local governments in developing cross cutting plans to address current and anticipated impacts of climate change.[82]

RELATED FUNDING OPPORTUNITIES

Taxes; state and federal grants; bonds; partnerships.

Private partnerships can help with the establishment of a CRO. In 2019, the city of Houston, Texas appointed a CRO to lead the city's partnership with 100 Resilient Cities. The partnership included funding for the CRO position that was sponsored through $1.8 million in funding by Shell Oil Company. Houston's CRO also reports directly to the mayor and oversees the development and implementation of a comprehensive Resilience Strategy for the city.

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80 Morales-Burnett, J and Marx, Rebecca. "The Rise of the Chief Resilience Officer." Urban Institute. 2022. https://www.urban.org/sites/default/files/2022-09/Rise%20of%20CROs%20Brief.pdf.
81 State of New Jersey. Executive Order No. 89. 2019. https://nj.gov/infobank/eo/056murphy/pdf/EO-89.pdf.
82 "Interagency Council on Climate Resilience." n.d. Climate Change (blog). New Jersey Department of Environmental Protection. https://dep.nj.gov/climatechange/resilience/resilience-council/.

A2. Local Adaptation Program

Incentivize or otherwise promote municipal and regional climate change vulnerability assessments and adaptation plans and establish grant programs or financing mechanisms to fund associated adaptation projects that build local resilience.

Promote local efforts to build resilience by establishing grant programs and funding pathways for adaptation projects.

KEY METRICS

Climate hazard risks reduced: All

Benefits: Enables the assessment of climate risks and establishes of adaptation plans on the local level. Provides funding to advance adaptation projects.

Costs: $-$$$

Emissions impacts: positive or neutral

Resulting Impacts

Funding opportunities, such as grant programs and other financing mechanisms, help increase access to climate assessments and adaptation projects across the state. For example, in 2022, New York State was able to approve nearly $450 million in grant programs available to New York municipalities for projects to improve water systems and infrastructure as a part of the state's Clean Air, Clean Water and Green Jobs Environmental Bond Act.[83] Climate change vulnerability assessments and adaptation plans identify risks, seek strategies to reduce vulnerability to projected climate change effects, and increase the local capacity to adapt. When implemented on the local level, these reports can provide detailed information on risks to the local community and tailored guidance on implementing adaptation projects and building local resilience to climate risks.

Equity Implications

Additional funding will be needed to construct adaptation projects. Expanding funding and technical assistance opportunities can help increase access to these long-term investments. Financial support and technical assistance need to be available to ensure low-wealth, marginalized, and minoritized communities can support adaptation plans and projects. These communities often face more risk and a higher need for infrastructure changes and transition. Programs such as the Clean Water State Revolving Fund that offer low-cost financing for water quality projects, provide examples of potentially more accessible financing options. In Pennsylvania, these funds are used to treat emerging contaminants and lead service line replacement.[84]

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[83] "Governor Hochul Announces $425 Million in Grants for Critical Water Infrastructure Projects Statewide." New York State, Governor's Office. April 17, 2023. https://www.governor.ny.gov/news/governor-hochul-announces-425-million-grants-critical-water-infrastructure-projects-statewide.
[84] Chou, B; Hammer, B; Levine, Larry. "Using State Revolving Funds to Build Climate-Resilient Communities." NRDC Issue Paper June 2014 (IP:14-06-A) https://www.nrdc.org/sites/default/files/state-revolving-funds-IP.pdf.

Implementation Considerations

Grant programs can be focused toward the most pressing climate hazard risks faced by the Commonwealth. Funding opportunities for adaptation projects and planning can also be focused on financially distressed communities that face high climate risk to expand access where it is most needed. Funding and incentives for programs like Resilience Hubs can also help establish networks across the Commonwealth. Additional resources providing technical assistance and information on how to access these opportunities may need to be made available to local governments and communities.

Lessons may be available from how other states have structured similar programs, such as:

- New York Climate Resilience Grant Program
- Virginia Community Flood Preparedness Fund Grants and Loans
- Resilient Virginia Revolving Loan Fund
- Resilient Florida Program
- Massachusetts Municipal Vulnerability Preparedness Program
- Massachusetts Coastal Resilience Grant Program
- Resilience Hubs and Networks Grant

Updates to the municipal planning code could also help municipalities increase resilience to climate change impacts. These updates can continue to help promote energy efficiency standards and sustainable materials.

RELATED FUNDING OPPORTUNITIES

Direct opportunities for states from federal sources have helped fund Pennsylvania State energy projects in the past. Since 2015, Pennsylvania has received over $150 million from the Weatherization Assistance Program and over $16 million from the State Energy Program (DOE) resulting in the creation of over 1,300 jobs and over 500 workshops, webinars, trainings, and the weatherization of nearly 12,000 homes, reducing energy costs. As a part of the program, for the 2021 to 2022 fiscal year, DEP approved over $41,000 in rebate vouchers for energy efficiency measures for agricultural producers, including LED lighting and controls, high efficiency ventilation fans and controls, and efficient milk pumping equipment.

Cost Considerations

Program funding needs can vary greatly depending on local and regional needs and resources. For example, the Virginia Community Flood Preparedness Fund was established to support regions and localities across the state in reducing impacts from flooding. The program has total funding of $85 million and allocates 25% of disbursed funds in low-income areas, giving priority to projects that implement community-scale hazard mitigation activities using nature-based solutions to reduce flood risk.[85] The Resilient Virginia Revolving Loan Fund has different funding options such as $5 million in loans to localities to meet local cost-share requirements for federal flood mitigation grants, $7.5 million in loans for buildings hazard mitigation, and $5 million in grants for creating local resilience funding programs.[86]

[85] "Community Flood Preparedness Fund Grants and Loans." Virginia Department of Conservation and Recreation. March 19, 2024. https://www.dcr.virginia.gov/dam-safety-and-floodplains/dsfpm-cfpf.

[86] "Community Flood Preparedness Fund Grants and Loans." Virginia Department of Conservation and Recreation. March 19, 2024. https://www.dcr.virginia.gov/dam-safety-and-floodplains/dsfpm-cfpf.

A3. Nature-Based Solutions

Pennsylvania can promote the use of nature-based solutions (NBS) to reduce climate risks, such as flooding, combined sewer overflow, or extreme heat.

NBS includes infrastructure such as green roofs, vegetated drainage basins, bioswales, riparian buffer zones, stormwater parks, and urban street trees. The Commonwealth should incentivize the use of NBS, also known as green infrastructure, in new developments and for renovations and retrofits. Pennsylvania should support public efforts to design new and retrofit existing infrastructure with NBS. NBS should be used as a catalyst to reduce climate risk while providing co-benefits such as creating natural areas for ecosystem habitat restoration.

KEY METRICS

Climate hazard risks reduced: Flooding, Extreme Heat

Benefits: Flooding and heat risk reduction, economic development, ecosystem services, outdoor recreation, beautification, and more

Costs: $$-$$$

Emissions impacts: Positive or Neutral

Resulting Impacts

NBS plays a crucial role in enhancing climate resilience within communities and can provide innovative and long-lasting solutions to flooding hazards and urban heat islands. Often, NBS infrastructure are cost effective and multifunctional, providing shade for cooling, stormwater management, recreational opportunities, and wildlife habitat through integrated green space. NBS can also aid in the safe and productive use of contaminated properties impacted by flooding by providing water quality benefits.

NBS projects can also support economic development by providing safe access walkways and bike routes to commercial areas. These walkways and interconnected green spaces in flood-prone areas surrounded by natural vegetation are welcoming and help promote increased foot traffic and enhance social interaction in communities, which in turn can increase revenue of local businesses and improve social cohesion and health. NBS can also be designed with inviting natural features, such as urban street trees that provide shade and additional green space for outdoor social and recreational activities.

Equity Implications

Many EJ areas have a need for infrastructure improvements which can be a catalyst to implement NBS. Green infrastructure projects can be multifunctional and help mitigate climate risks while bringing other environmental, social, economic and health benefits to EJ communities. For example, a stormwater park with urban street trees can increase connectivity for pedestrians, reduce urban heat islands, provide flood protection, and increase green space for recreation.

NBS provides benefits that target key issues affecting EJ communities related to poor air quality, elevated flood risk, and more environmental health challenges. Additional incentives in the form of funding opportunities can be implemented for projects located in EJ areas to expand these benefits in communities with the highest need. NBS projects in EJ areas should also consider any present cultural relationships to natural resources that play an important role in the community.

Implementation Considerations

The diverse benefits brought by NBS often allow for eligibility through a variety of state and federal funding opportunities depending on the project details and the impacts addressed. Opportunities include grants for the cleanup and redevelopment of brownfields or funding for stormwater parks to reduce flooding and improve surface water quality. Philadelphia's stormwater management plan, Green City, Clean Waters serves as a leading example in Pennsylvania and across the country of a successful NBS implementation. The program focuses on investments in bioswales and stormwater trenches to manage rainfall in the city in lieu of intrusive and expensive sewer replacement projects. The plan is designed to provide social, economic, and environmental benefits in addition to stormwater management by providing green space and shade in the dense urban area. The plan includes $2.4 billion in funding for green infrastructure capital construction and operating and maintenance costs over a 25-year period.

Both existing plans and model ordinances, such as the Act 167 Stormwater Management Model Ordinance, and dedicated green infrastructure plans, can be utilized and expanded to cover NBS. These ordinances can embrace NBS and low-impact, resilient development practices such as replacing impermeable surfaces with permeable pavement, rain gardens, and other blue-green infrastructure. Existing resources, such as Montgomery County's model ordinances and design guidebooks, include sustainable green parking lot guidelines, floodplain ordinances and other guides for regulations and adaptive reuse.[87]

Additional incentives can also be provided to encourage the adoption of NBS investments. For example, municipalities can provide density bonuses for buildings with green roofs, allowing developers to build more floors or units. Cities can also offer direct financial incentives for installing green roofs, rain barrels, or other green infrastructure.

RELATED FUNDING OPPORTUNITIES

Taxes, state and federal grants, bonds, public-private partnership can all be used to fund nature-based solutions. Nature-based solutions can provide significant co-benefits. Because of this, funding opportunities targeted at ecosystem restoration or recreation can be utilized to implement nature-based solutions to manage climate change.

[87] "Storm Preparedness, Flood Hazard Mitigation, and Community Resiliency." State Planning Board of Pennsylvania. 2021. https://dced.pa.gov/download/2021-storm-preparedness-flood-hazard-mitigation-and-community-resiliency/?wpdmdl=119170.

Cost Considerations

Costs can vary depending on the NBS improvement. For example, tree boxes, a stormwater control measure designed to collect and treat the first flush of stormwater prior to discharge into the storm sewer system or subsoil, can cost approximately $12,500 each according to one case study in New Jersey.[88] Another example of a NBS improvement, retrofitting green roofs, can have a much higher cost depending on the size of the project and the type of green roof being installed. Additional considerations include designing roofs with sufficient structural capacity to support the green roof. Maintenance activities can also add to costs over time with some projects requiring additional upfront maintenance to establish vegetation that is a part of the green infrastructure improvement.

Funding pathways, such as grants and public partnerships, help ensure that communities and developers have the financial resources to take on the costs associated with the construction and maintenance of NBS infrastructure improvements. For example, in 2022, New York State awarded over $18 million in grant funding to EJ communities for NBS projects through the state's Green Innovation Grant Program.[89]

[88] "FS1209: Green Infrastructure Practices: Tree Boxes." Rutgers New Jersey Agricultural Experiment Station. August 2013. https://njaes.rutgers.edu/fs1209/.
[89] "Funding Will Support Innovation to Help Scale Sustainable Solutions." New York State Energy Research and Development Authority. 2022. https://www.nyserda.ny.gov/About/Newsroom/2022-Announcements/2022-10-12-Governor-Hochul-18-Million-Available-for-Development-of-Innovative-Nature-Based-Solutions\.

A4. Utility Climate Risk Analysis

Climate risk assessments for water supply and energy utilities can help identify specific risks, actions, as well as gaps for additional research.

Pennsylvania should require and incentivize water and energy utilities to conduct climate risk assessments to further understand and disclose risks to the public, regulators, and investors. Assessments should identify key climate vulnerabilities, actions, and research opportunities to adapt and mitigate the identified risks.

KEY METRICS

Climate hazard risks reduced: Flooding; Heat; Power Outages

Benefits: Increase energy reliability

Costs: $-$$$

Emissions impacts: Positive or neutral

Resulting Impacts

Securing the reliability and resilience of water and energy utilities is a crucial step in mitigating climate change related impacts to the economy, human health, and physical safety. Climate risk analyses for utilities outline the specific risks and actions needed to ensure power-grids, water supply, and water treatment infrastructure can withstand extreme temperatures, flooding, and other extreme weather events. Requiring these assessments for local and regional water supply and energy utilities can help outline core infrastructure improvements needed to increase utility and community resilience. Examining local and regional risks to water supply and energy utilities can also help identify cases of vulnerabilities that may need additional research and technical assistance.

For investor-owned utilities, required climate risk analysis aligns with the proposed US Securities and Exchange Commission's expanded risk compliance guidelines under the 1933 Securities Act and the 1934 Securities Exchange Act. These new proposed rules would require public companies to disclose climate-related information, including GHG emissions and other climate-related risks to operations and assets.[90]

Equity Implications

Risk assessments should require an analysis of EJ concerns and equity considerations including specific impacts to vulnerable populations. When requiring climate risk assessments for water and energy utilities, the Commonwealth can provide guidance on how to prioritize equity considerations, such as customer characteristics (e.g., historically disadvantaged, households that use essential electronic medical equipment, etc.), when evaluating climate impacts on the system or selecting adaptation investments.

[90] "SEC Proposes Rules to Enhance and Standardize Climate-Related Disclosures for Investors." US Securities and Exchange Commission. 2024. Available: https://www.sec.gov/files/33-11275-fact-sheet.pdf.

Currently, expanding federal initiatives help increase the financial accessibility of climate resilience projects and planning work in EJ areas, including risk analysis. Many programs are supported by the US EPA through funding from the 2022 IIJA. As of September 2023, the Drinking Water System Infrastructure Resilience and Sustainability Program Grants will support $19 Million in grants to fund projects that combat climate change impacts on drinking water in underserved, small, and disadvantaged communities.[91]

Implementation Considerations

Requiring climate risk analysis for water supply and energy utilities throughout the Commonwealth requires that the state consider ways to advance additional information and financial resources. When research gaps and vulnerabilities are identified, there can be a variety of funding opportunities available at the state and federal level to support the investigation of adaptation solutions.

State regulatory bodies should have a role in integrating climate risk analysis into regulation. Entities such as the PA PUC can require disclosure of risk and provide guidance and resources to utility providers and consumers while continuing to track service reliability. For example, in 2022, New York State passed a law that required utilities to submit climate change vulnerability studies to the New York Public Service Commission in late 2023. The utilities were also required to submit climate resilience plans to the commission for approval. The costs for implementing the plan will be recovered in the utility's rate case following the Public Service Commission's determination. The Public Service Commission is set to approve or modify the resilience plans, following a public hearing, by late 2024.

Cost Considerations

Funding needs for local and regional utilities resilience assessments and planning can vary greatly. The costs associated with evaluating risk may result in higher utility fees evaluating risks; however, grant opportunities can be available at the state and federal levels.

The US DOE's Grid Deployment Office's Grid Resilience and Innovation Partnership (GRIP) program provided funding as a part of the IIJA to help improve power systems under the growing threat of extreme weather events and climate change. In 2023, the program announced up to $3.46 billion in investments for

RELATED FUNDING OPPORTUNITIES

Pennsylvania can require publicly regulated utilities to conduct climate risk assessments. Funding can be gathered from rate increases which can be subsidized by taxes, state and federal grants, or bonds. For example, The US DOE's Grid Deployment Office's Grid Resilience and Innovation Partnership (GRIP) program provided funding as a part of the Bipartisan Infrastructure Law to help power systems adapt to climate change.

[91] "Drinking Water System Infrastructure Resilience and Sustainability," 2024. US EPA. https://www.epa.gov/dwcapacity/drinking-water-system-infrastructure-resilience-and-sustainability

58 projects across 44 states to strengthen electric grid resilience and reliability across America. Later that year, the program announced an additional $3.9 billion available through Fiscal Years 2024 and 2025. The GRIP program provides funding through Grid Resilience Utility and Industry and Smart Grid Grants. Grid Resilience Utility and Industry Grants, totaling $2.5 billion in available funding, help modernize the electric grid by reducing impacts from extreme weather and natural disasters through funding for comprehensive transmission and distribution technology solutions that mitigate multiple hazards. The Smart Grid Grants program provides up to $3 billion in funding to projects that help to increase grid flexibility and address fault prevention, renewable energy integration, and electrifying vehicles and buildings.[92]

[92] "Grid Resilience and Innovation Partnerships (GRIP) Program," 2023. US Department of Energy Grid Deployment Office. https://www.energy.gov/gdo/grid-resilience-and-innovation-partnerships-grip-program

A5. Enhanced Workplace Health and Safety Protections

Climate change is projected to impact workplace health and safety especially with increasing heat. The Commonwealth can provide resources and promote statewide and local adoption of health, safety, and legal protections to protect workers from exposure to climate hazards.

Pennsylvania should expand resources for workplace health and safety such as expanded guidance and requirements around the use of personal-protective equipment (PPE) and multi-lingual health safety guides through state and local programs and partnerships. Regulatory changes may also be needed to protect vulnerable workers against evolving occupational health and climate risks, such as extreme heat and poor air quality.

KEY METRICS

Climate hazard risks reduced: Extreme heat

Benefits: Reduces risks to worker health and safety

Costs: $-$$

Emissions impacts: Negative or neutral

Resulting Impacts

Protecting the Commonwealth's workforce requires several improvements to current workplace health and safety standards and regulations. The Commonwealth can expand the implementation of several US Department of Labor recommendations laid out in the Workforce Innovation and Opportunity Act State Plans while advancing state-level legal protections and requirements to protect workers from exposure to dangerous conditions that are projected to increase as climate change progresses. New regulations need to be flexible and responsive to climate change impacts that may grow over time, allowing state and local governments to adjust to changing adaptation needs and worsening conditions.

Equity Implications

Vulnerable populations need to be a point of focus when advancing protections as many occupational climate hazards disproportionately affect these groups. Generally, workers who are members of historically disadvantaged groups are also more likely to be employed in jobs that face increased occupational climate hazards while living in areas disproportionately affected by climate impacts to air quality, temperature, and water quality. Workers' risk can also be influenced by their immigration status. For example, undocumented workers often lack the same resources and protections afforded to workers with legal immigration status.

The adoption of legal requirements for workplace health and safety helps set standards for employers to follow as workers face increased risk. However, additional measures need to be taken to ensure that workers facing complex challenges can access information, protective equipment, and other resources. Informational resources, including safety training provided to workers and instructions for using protective equipment, need to be multi-lingual and accessible. Outreach should be conducted to ensure that vulnerable populations can easily access resources and report occupational hazards regardless of language or immigration status.

Implementation Considerations

Alongside regulatory changes, outreach is crucial to increasing workplace safety and accessibility to resources. Both workers and employers need to be informed about occupational climate risks affecting their jobs and industries. Once informed about the increased risks brought on by climate change, workers and employers should be provided with additional resources and guidance on risk mitigation efforts such as expanded PPE, cooling areas for outdoor workers, and other safety measures. Both workers and employers should be informed early on of initiatives to make regulatory changes and opportunities for public comment.

Supporting state and local efforts to advance worker protections also means investigating the diverse ways that climate change will affect workers over time. This includes health impacts, potential income loss from missed days of work for outdoor workers, and employment changes faced by workers due to the transition to larger economic trends in climate mitigation (i.e., shifting toward cleaner electricity generation). In addition to strengthening protections against extreme heat, state and local agencies should seek to uplift and provide financial support pathways for at-risk workers to receive training in emerging climate resilient jobs. For example, alternative farming practices, such as Controlled Environment Agriculture (CEA), can potentially provide solutions to climate change driven impacts to farm worker health and safety. CEA is a sustainable approach to farming that involves producing crops within a climate-controlled structure, offering increased biosecurity and year-round production without pesticides or herbicides.[93] These practices can provide safer options for agricultural workers and may require additional research and resources to address operational needs such as renewable energy resources. Agricultural workers that face increased climate impacts can obtain additional training to gain access to safer, more resilient jobs.

Programs utilized in other states can serve as examples for new programs that can be applied in Pennsylvania to support workers. Through the IRA, the National Oceanic and Atmospheric Administration (NOAA), through the Climate-Ready Workforce for Coastal and Great Lakes States,

RELATED FUNDING OPPORTUNITIES

Taxes, state and federal grants, bonds, public-private partnership can all be used to fund improved measure for worker safety from climate impacts. For example, through the Inflation Reduction Act, NOAA assists employers in developing a climate resilient workforce. Grants support workforce training and job placement related to climate resilience in underserved communities. NOAA plans to make between 10-20 awards annually, at amounts ranging from $500,000-$10 million each.

[93] "The Ultimate Guide: Controlled Environment Agriculture (CEA) Types & Requirements," 2024. https://clearcomfort.com/guide-controlled-environment-agriculture-cea-types-requirements/#:~:text=CEA%20farming%20is%20where%20agricultural,resource%20efficiency%20and%20profitable%20sustainability.

Tribes, and Territories Initiative, seeks to provide funding for programs to assist employers in developing a climate resilient workforce. These grants will support workforce training and job placement related to climate resilience in underserved communities. NOAA plans to make between 10-20 awards for the 2024 competition, at amounts ranging from $500,000-$10 million each.[94]

A6. Evaluation of Equity Impacts

Require the evaluation of EJ communities and other historically disadvantaged and marginalized groups when assessing climate risk and adaptation strategies, to ensure equitable distribution of risks and benefits.

Pennsylvania should require state agencies and local governments to evaluate EJ issues when conducting climate risk assessments. EJ communities should be considered when identifying and implementing adaptation strategies to ensure historical disadvantages and vulnerabilities are addressed, future risks are equitably mitigated, and adaptation measures do not inadvertently cause future harm. The state should provide standardized methods and guidance to evaluate EJ communities. This process will help to ensure equitable distribution of risks and benefits.

KEY METRICS

Climate hazard risks reduced: All

Benefits: Promotes meaningful engagement with communities most at risk while seeking the equitable distribution of risks and benefits

Costs: $-$$$

Emissions impacts: Neutral

Resulting Impacts

Climate change impacts are multifaceted, creating new challenges to public health and safety while amplifying pre-existing inequities. Centering EJ requires robust efforts to understand historical impacts, solicit input from communities, and analyze equitable risk mitigation options.

Long-term, meaningful engagement with EJ issues throughout the Commonwealth can help build trust with communities. Enhancing community engagement in EJ areas can help identify additional opportunities to expand protections, address community needs through adaptive infrastructure, and invest in additional resources.

[94] NOAA, "Climate-Ready Workforce," 2024. https://www.noaa.gov/inflation-reduction-act/inflation-reduction-act-climate-ready-coasts-and-communities/climate-ready-workforce

Equity Implications

Expanding guidance on how to engage communities and address EJ issues is essential to ensuring state and local agencies can identify and address complex EJ issues. To help with this effort, in 2023, the Pennsylvania DEP updated its EJ area definition to include a broader set of criteria for identifying EJ areas and promote a community outreach-first approach and an enhanced public participation process. Beyond the engagement process, many of these EJ issues already have proven solutions, some of which have been implemented in the Commonwealth. A more unified effort to identify issue areas, deploy these solutions, and monitor outcomes will help create long-lasting climate and equity benefits for EJ communities. Continued community engagement in EJ areas can guide how these solutions are implemented and sustained.

RELATED FUNDING OPPORTUNITIES

Evaluating equity impacts and actions for EJ communities can provide many co-benefits and increase the range of eligible funding opportunities targeted at disadvantaged and marginalized groups to build climate resilience.

Implementation Considerations

Requiring evaluation of EJ communities and vulnerable populations in climate risk assessments and strategy development must be supported by efforts to expand the existing tools for community engagement, project planning and information sharing as well as training materials. These tools will require additional funding and in-house expertise to create and facilitate. Currently the US EPA supports environmental and climate justice activities to benefit underserved and overburdened communities through the Environmental and Climate Justice Program, created by the IRA.[95]

An example of how EJ projects have been implemented in the past can be found across the Delaware River in New Jersey. In 2023, US EPA selected six projects lead by two community organizations, the state of New Jersey, and three city agencies to receive over $4.8 million in funding through the Environmental Justice Collaborative Problem Solving Cooperative Agreement and the Environmental Justice Government-to-Government programs. The selected projects will focus on community outreach, climate resilience and nature-based programming among other focus areas and goals.[96] The projects were locally developed by community organizations and state and local governments across New Jersey, and Pennsylvania can look to its neighbor as a blueprint for how to acquire funding and implement locally developed programs that evaluate and address equity impacts for EJ communities.

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[95] "Inflation Reduction Act Environmental and Climate Justice Program." US EPA. 2023. https://www.epa.gov/inflation-reduction-act/inflation-reduction-act-environmental-and-climate-justice-program.

[96] "New Jersey Organizations and Agencies Slated to Get Over $4.8 Million in EPA Funding to Support Environmental Justice Work," US EPA. 2023. https://www.epa.gov/newsreleases/new-jersey-organizations-and-agencies-slated-get-over-48-million-epa-funding-support#:~:text=NEW%20YORK%20-%20Today%2C%20the%20U.S.%20Environmental%20Protection,part%20of%20President%20Biden%E2%80%99s%20Investing%20in%20America%20agenda.

A7. Climate Resilient Design Guidelines

Create guidance to incorporate climate projections into built infrastructure design.

Pennsylvania should create guidance for public and private entities (e.g., planning commissions, trade councils, departments of transportation, etc.) to incorporate climate projections into built infrastructure design with the goal of mitigating climate impacts to exposed infrastructure. Guidance may be standalone or more comprehensive (i.e., enhanced building and zoning codes). Design guidelines should require flood protection measures and building improvements for structures exposed to future projected sea level rise, extreme precipitation, and heat events, among other climate hazards.

KEY METRICS

Climate hazard risks reduced: All

Benefits: Reduced infrastructure damage from extreme events

Costs: $-$$$

Emissions impacts: Positive or neutral

Resulting Impacts

Several states and localities have adopted climate resilience design guidelines. Providing guidance for incorporating climate projections into infrastructure project design helps ensure that best practices are used when siting and designing infrastructure that is climate resilient. State provided guidance can ensure that historical and future climate hazards are considered when planning and managing all aspects of infrastructure activities, including concept development, asset planning and design, construction, operations, maintenance, monitoring, renewal, and disposal. Climate resilient infrastructure can be designed to withstand current and future extreme weather events, protecting residents, and reducing losses from damage. For example, one study by the National Institute of Building Sciences found that natural hazard mitigation, through building improvements and code changes, saves $6 in damage costs for every $1 spent on federal mitigation grants.[97] Climate resilient design standards also allow infrastructure to continue providing shelter and resources to citizens during extreme weather events. Existing climate-smart design guidelines, such as envelope requirements and options described in the Pennsylvania Residential Alternative Energy Provisions report, can be expanded on and combined into a set of required and recommended improvements.[98]

Equity Implications

Climate guidance should provide insight on analyzing EJ concerns that are potentially exacerbated with no action and documenting existing research and available information relevant to EJ communities. Embedding equity in the design and implementation of climate design

[97] "Natural Hazard Mitigation Saves Interim Report." FEMA. 2018. https://www.fema.gov/sites/default/files/2020-07/fema_mitsaves-factsheet_2018.pdf.
[98] "Pennsylvania Alternative Residential Energy Provisions." Pennsylvania Housing Research Center. 2018. https://www.phrc.psu.edu/assets/docs/Publications/2018_Pennsylvania_Alternative_Energy_Provisions.pdf.

guidance helps to ensure that actions respond to social inequities and the needs of those who are most vulnerable, improves the effectiveness of climate policy, and wins greater public support for state and local climate planning while working to prevent maladaptation due to unrecognized and unaddressed EJ issues.[99] Stricter design guidelines can result in higher upfront construction costs, and guidelines should consider cost and protection tradeoffs. Financial resources need to be made available to members of EJ communities to ensure that low-income populations can make the necessary improvements.

Implementation Considerations

The Commonwealth can support the incorporation of climate projections into built infrastructure design by developing and promoting industry standards, mandates, guidance, and training for using climate projection data in architecture and engineering applications. Pennsylvania building regulations are outlined in the Commonwealth's Uniform Construction Code (UCC). While the UCC does not directly address climate change concerns, included regulations—such as building envelope requirements—help with energy efficiency. The Commonwealth also enforces additional standards and requirements to advance energy efficiency. For example, Pennsylvania requires that new construction projects and renovations by state agencies achieve a 10% reduction in energy consumption over the American Nation Standard model energy code.

Financial support for these changes is crucial to ensure buildings can be updated to meet new mandates. For example, under a 2022 Massachusetts state mandate, windows need to retain a certain amount of heat indoors to meet efficiency standards. Depending on the home improvements needed to meet code requirements, one study found that the new code could increase the cost of construction of single-family homes and townhouses by roughly $10,000 to $23,000 for the median single-family home.[100] Assistance for these costs should be considered in the implementation of new codes and standards to ensure that citizens and communities can adapt. Making these improvements leads to long-term avoided losses and energy efficiency savings. One study found that modern building codes can reduce property losses by up to 25% from natural disasters, such as extreme wind and precipitation.

RELATED FUNDING OPPORTUNITIES

Grants, bonds, and public-private partnership can all be used to fund the development of climate resilient design standards. Implementing these guidelines or standards may reduce hazard risk and lower insurance premiums for property owners.

[99] "How to embed equity and inclusivity in climate action planning," C40. 2023. https://www.c40knowledgehub.org/s/guide-navigation?language=en_US&guideArticleRecordId=a3s1Q000001iaiBQAQ&guideRecordId=a3t1Q0000007lEWQAY.
[100] Bakhshi, P., et al., "Public Policy for Net Zero Homes and Affordability," 2023. https://hbrama.com/wp-content/uploads/2023/05/Public-Policy-for-Net-Zero-Homes-and-Affordability-Final-6-14-23.pdf.

A8. Enhanced Emergency Management

Expand existing extreme weather emergency response management to consider the increased frequency and severity of extreme weather events due to climate change.

Implement measures that enhance and improve emergency management capabilities to improve pre-disaster communication and preparedness, emergency response, and disaster recovery. Measures include but are not limited to enhanced early warning systems, additional staffing and equipment, public outreach, and additional training. Incorporate climate projections in emergency management planning to prepare for changes in frequency, severity, and types of hazard events.

KEY METRICS

Climate hazard risks reduced: All

Benefits: Improve safety during and more rapid recovery after extreme events

Costs: $-$$$

Emissions impacts: Positive or neutral

Resulting Impacts

Enhanced disaster management is crucial to ensuring that communities can adapt, withstand, and recover from extreme weather events brought by climate change. The increasing frequency of severe weather events such as hurricanes, floods, and wildfires, pose significant challenges to public health, safety, and economic vitality, causing widespread impacts that can be challenging to address simultaneously. By enhancing emergency management services, communities can be given additional resources and planning tools to withstand, absorb, and recover from extreme weather events. Extreme weather events can cause major disruptions in energy, transportation, and water infrastructure systems, potentially causing cascading impacts to public health and safety. Households may be temporarily or even permanently displaced, and some residents may be unable to relocate from impacted areas, requiring additional emergency response services to recover from extreme events.

Localities can collaborate across agencies and sectors to address risks holistically and reduce risk for vulnerable populations. Solutions implemented can establish and strengthen early warning systems and expand outreach and education in communities. Additional training and guidance can also be provided to better equip emergency services to understand increased climate change risks and expand preparedness capabilities for future severe weather events that will increase in severity over time.

Equity Implications

Communities in EJ areas often bear the brunt of extreme weather events. Enhanced emergency management must include heightened support to address cumulative risks and cascading events experienced by communities in EJ areas. These risks represent the combined impact of multiple stressors, including environmental hazards, socioeconomic factors, and historical inequities. Equitable disaster risk reduction considers community members and populations who face barriers in receiving assistance, such as financial, linguistic, mobility and historical barriers, and are disproportionately affected by disasters. When implementing enhanced emergency management measures, agencies and local governments across the Commonwealth must enable community participation and meaningful engagement as a part of the decision-making process.

Implementation Considerations

Improving disaster management and response requires an integrated approach that ensures efficiency across all systems and parties involved. The Commonwealth can leverage and expand on existing grants and programs to support the continued integration of climate impacts into existing comprehensive disaster preparedness and assistance plans across the state. For example, the Emergency Management Performance Grant (EMPG) program supports preparedness and assistance plans, capabilities, and programs in Pennsylvania counties. The program focuses on all-hazards, emergency preparedness, and evolving risks associated with climate change. In FY2023, the Commonwealth allocated $10.9 million for the EMPG program.[101] These funds are appropriated by Congress and allocated to states by FEMA for emergency management agencies and local jurisdictions. Costs can include planning, organizing, equipment, training, travel, construction, renovation, operational overtime, and maintenance.

RELATED FUNDING OPPORTUNITIES

Taxes, state and federal grants, bonds, and public-private partnerships can all be used to enhance emergency management. FEMA grant programs for emergency preparedness such as the Emergency Management Performance Grant (EMPG) program, supports preparedness and assistance plans, capabilities, and programs. The FEMA Regional Catastrophic Preparedness Grant Program (RCPGP) supports the building of core capabilities essential to achieving the National Preparedness Goal of a secure and resilient nation.

[101] “Emergency Management Performance Grant (EMPG) (Pennsylvania).” Grants Office. 2023. https://www.publicsafetygrants.info/Grant-Details/gid/34019.

A9. Property Risk Disclosures

Adopt and enforce requirements for property owners to disclose information about a building's propensity to flood when renting or selling the property and include information on whether mold remediation has been or will need to be conducted.

Implement and enforce measures that ensure property owners have a disclosure obligation to help potential buyers and renters understand the associated physical climate risks and transition risks associated with the property. Expand upon existing disclosure requirements that currently exist for property sellers to disclose flood risk to buyers to include renters and information on mold remediation. Ensure buyers and renters are fully informed of a property's flood risk before buying or entering into a lease agreement.

KEY METRICS

Climate hazard risks reduced: All

Benefits: Helps ensure property owners inform prospective buyers or renters of relevant risks

Costs: $

Emissions impacts: Neutral

Resulting Impacts

While some risk disclosure is already required, such as flood risk disclosure for property buyers, not all risks impacted by climate change are covered under current regulations, and enforcement is inconsistent. For example, mold remediation in rental disclosures is not required. Climate change can worsen these risks and increase the likelihood that renters and buyers will face property damage, health risks, and potentially be forced to relocate. These impacts could potentially be mitigated through the installation of resilience measures.

Enhanced disclosure requirements support transparency and enable better risk management and mitigation. Having consistent and comparable information about climate risks and opportunities benefits both investors and real estate organizations.

Implementation Considerations

Laws can be made or changed to accommodate additional property risk disclosure. In New Jersey, for example, flood risk disclosure is currently being expanded to include obligations for landlords.[102] Changing regulations will require including guidelines for real estate firms, property owners, buyers, and renters. For example:

- Flood risk information should be clear and concise.
- Risk disclosure forms should be provided early in the renting/selling process.
- Accurate information should be gathered and provided about the property's flood history.

Regulatory change will require close collaboration and outreach to landowners and real estate industry entities to ensure that disclosure requirements can be met and do not impose too much of a burden on the real estate industry, including smaller landlords and real estate firms. Early outreach and engagement can help identify industry concerns as new regulations are being drafted to ensure adequate public comment and stakeholder input.

Equity Implications

By expanding risk disclosure to renters, state agencies can ensure residents make informed decisions when choosing where to live. Renters are often limited in the risk mitigation measures and improvements they can make when facing climate risks in a new residence. Additionally, much less assistance is available to renters for disaster relief as compared to homeowners.[103] Renters also have less mobility to move out of affected areas amid rising rental costs and a depleted housing stock. If left uninformed of the potential risks, renters cannot mitigate the potentially major damages and health and safety impacts caused by climate hazards. Low-income renters have even less resources to withstand and recover from climate impacts.

RELATED FUNDING OPPORTUNITIES

Taxes, state and federal grants, and public-private partnerships can all be used to help provide funding for outreach and engagement efforts with the real estate community, homeowners, renters, and buyers to ensure the disclosure guidelines are fair, realistic, and implemented.

[102] "Flood Risk Notification." NJDEP. 2023. https://dep.nj.gov/flooddisclosure/.
[103] Martín C., et al. "Disasters and the Rental Housing Community." Brookings. 2023. https://www.brookings.edu/articles/disasters-and-the-rental-housing-community/.

A10. Health Impacts Tracking

Encourage public health agencies to track and analyze health data to better understand climate-related health impacts, including heat, flooding, and vector-borne diseases.

Support health agencies, including the Pennsylvania Department of Health, and municipal departments of public health, in taking steps to report and address high-risk climate-related health impacts. Establish a set of key health indicators, such as signs of heat stress, or vector-borne diseases associated with climate impacts, to ensure universal tracking of climate-related health impacts across the state. Collaborate with medical institutions and service providers to ensure reliable reporting. Provide guidance on how to analyze data and information about what types of health trends can be attributed to climate change or other factors.

KEY METRICS

Climate hazard risks reduced: All

Benefits: Improved ability to manage public health impacts from climate change over time

Costs: $

Emissions impacts: Neutral

Resulting Impacts

Currently, the Pennsylvania Department of Health tracks climate-related public health impacts through multiple state programs. The Environmental Public Health Tracking (EPHT) program monitors environmental exposures and related health outcomes, measuring changes over time and differences between regions in the state. The program also works with other state programs, such as the Pennsylvania Occupational Safety and Health Surveillance Program and the Asthma Control Program, to act as a centralized source of accessible and accurate information and address EJ concerns. EPHT has resulted in the creation of publicly available resources for accessing health impacts data, such as the Pennsylvania Environmental Health Indicators Map. Programs like EPHT can be expanded to include additional climate-related health impacts, such as mold-related illnesses and vector-borne diseases, and provide additional support to local agencies and resources for local initiatives to improve public health and address climate-related hazards.

Improving public health tracking throughout the state can include increased community engagement, improved data visualization platforms and data accessibility, and enhanced cross-sector collaboration. Enhancing statewide climate-related public health data can help support new research into environmental and public health issues through improved data and resources.

Equity Implications

While EPHT seeks to understand and address disparities faced by communities in EJ areas, it is important to ensure that resources are accessible to diverse populations. This may include providing factsheets and other informational materials in multiple languages and having a public location for citizens to retrieve resources on local public health. Strengthening community partnerships with local stakeholders, environmental organizations, and health departments is also key to ensuring informational materials are accessible and accurate. Community members can be included in data collection, interpretation, and sharing, as well as future action planning. This can help provide a platform for community members to voice concerns and contribute important community needs and knowledge to ongoing environmental and public health tracking. Educational workshops also serve as opportunities to improve health literacy in the Commonwealth and empower residents to understand risks and take preventive measures.

Implementation Considerations

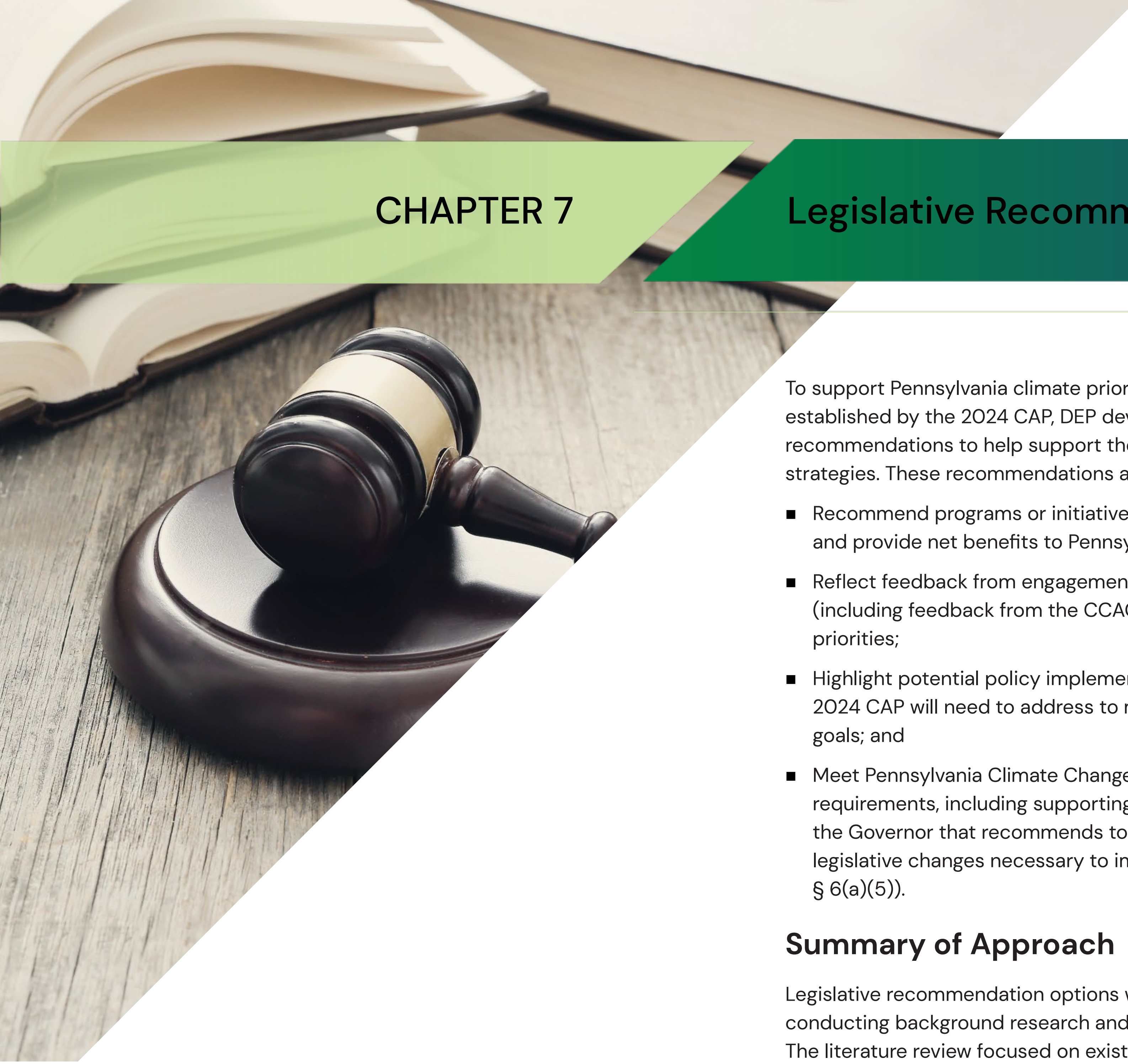
Some federal programs can help states cover costs for initiatives to track climate-related public health data. For example, EPHT is funded by the Center for Disease Control and Prevention's (CDC) National Center for Environmental Health. Other programs, such as the CDC's Climate and Health program provide grants, as well as communication products and guidance, to support state, Tribal, local, and territorial public health agencies prepare for climate-related health impacts. Specific funding amounts can vary depending on program need. The Commonwealth can also seek to support future collaboration and research to investigate cumulative health impacts and solutions. For example, in 2023, the EPA awarded over $21 million in grant funding to 16 institutions for community-based research on cumulative health impacts.[104]

Ensuring that heat-related illness and other environmentally-sourced health impacts are properly coded within databases is also a critical implementation consideration. Providing guidance and training for healthcare professionals on reporting environmental conditions as contributing factors in relevant cases can help improve reporting.

RELATED FUNDING OPPORTUNITIES

State and federal grant programs or public-private partnerships could fund health impacts tracking programs. The EPA awarded over $21 Million in grant funding to 16 institutions for community-based research on cumulative health impacts.

[104] "EPA Announces $21M in Research Grant Funding to Investigate Cumulative Health Impacts of Climate Change on Underserved Communities," US EPA. 2023. https://www.epa.gov/newsreleases/epa-announces-21m-research-grant-funding-investigate-cumulative-health-impacts-climate.



CHAPTER 7 Legislative Recommendations

To support Pennsylvania climate priorities and the needs established by the 2024 CAP, DEP developed legislative recommendations to help support the implementation of identified strategies. These recommendations aim to:

- Recommend programs or initiatives to reduce GHG emissions and provide net benefits to Pennsylvania;
- Reflect feedback from engagement with interested parties (including feedback from the CCAC) to address state climate priorities;
- Highlight potential policy implementation pathways that the 2024 CAP will need to address to meet Pennsylvania climate goals; and
- Meet Pennsylvania Climate Change Act of 2008 (Act 70) requirements, including supporting DEP in submitting a CAP to the Governor that recommends to the General Assembly legislative changes necessary to implement the CAP (Act 70 § 6(a)(5)).

Summary of Approach

Legislative recommendation options were first developed by conducting background research and a high-level literature review. The literature review focused on existing and currently proposed

Pennsylvania legislation to identify future opportunities for effective legislation. Additionally, it evaluated best practices of existing climate and energy policies in other neighboring states to develop a menu of legislative options. Large and comprehensive, the menu was then presented to the CCAC and further developed based upon feedback received. DEP then refined the menu to a short list of recommendations based on the following evaluation criteria:

- **Meets a need established in the 2024 CAP to achieve GHG reduction goals** (e.g., clean energy grid, building decarbonization, EV deployment).
- **Meets needs communicated by interested parties** since the inception of Act 70, with particular focus on findings from engagement with interested parties conducted since the publishing of the 2021 CAP. Sources of stakeholder needs included:
  - Identified impacts to/opportunities for communities facing EJ issues, provided from recent Pennsylvania Climate Action: Strategies for Environmental Justice Communities report
  - Input received via CPRG outreach
  - Input from other applicable existing outreach received by DEP
- **Advances a cost-effective strategy recommendation that shows a net benefit to interested parties and/or the public.**
  - Net cost/benefits vs. social cost of carbon were identified to be beneficial to participants.
- **Demonstrates practice of similar policies in other states and jurisdictions,** as identified by the literature review.
- **Leverages existing regional clean energy and other climate programs and policies.**
- **Introduces a new consideration or fills a gap left by existing and currently proposed legislation.**

Other states have developed and passed comprehensive legislative packages, such as the Maryland Climate Solutions Now Act or New York's Climate Leadership and Community Protection Act. Compiling all of the proposed recommendations into a similarly comprehensive package could be a successful approach to ensure broad implementation of CAP strategies.

List and Description of Recommendations

Based on the identified criteria, DEP developed the following legislative recommendations to advance implementation of the 2024 CAP:

- Building Code Reform
- Community Solar
- ZEV Targets
- Low-Carbon Fuel Standards
- Pennsylvania Reliable Energy Sustainability Standard (PRESS)
- Pennsylvania Climate Emissions Reduction Act (PACER)
- Hydrogen Legislative Package

Each recommendation was reviewed for a level of maturity in the Pennsylvania legislative landscape. Recommendations labeled as "Ready for advancement" met the following criteria: either they have more robustly developed discussion of key policy considerations and/or are being actively discussed by legislators with multiple draft legislative proposals either in development, in committee, or having been discussed. Less mature recommendations with fewer legislative proposals, and/or less robustly developed discussion of key policy considerations are considered “Needs further development.” Categories of recommendation maturity used in this CAP are detailed below.

Table 20. Categorization of Legislative Recommendations Key

Maturity Category	Envisioned Next Steps
Needs further development	Detailed discussion and further development of key policy considerations; development of legislative proposals
Ready for Advancement	Key policy considerations are developed and have achieved consensus; legislative committee discussion; consolidation, refinement, and passage of existing legislative proposal

Building Energy Code Reform

Ready for Advancement

State building energy codes set minimum energy efficiency levels for residential and commercial buildings throughout the Commonwealth. Pennsylvania’s existing process for adopting updated building energy codes requires a RAC approval process, in which members of various industry sectors review and make recommendations for proposed changes to Pennsylvania’s UCC. Currently, the RAC is required to review the International Codes Council’s updated code three years after it has been adopted. This means that Pennsylvania is automatically behind other states in adopting the latest model energy code. In addition, there is little autonomy for municipalities to adopt a more stringent building code—such as a zero-energy code—so it is up to designers and builders if they choose to treat the UCC as a minimum. Lastly, the RAC calls for volunteers to assist in technical reviews of the codes, but there is no cost, life cycle cost, or similar economic analysis required of the code recommendations made by these technical review committees.

This recommendation is to adopt the latest building energy codes in Pennsylvania in a timelier manner, allow municipalities to opt into a more resilient code and ensure the RAC has the best economic information to make decisions during the code review process.

Key Policy Considerations

When developing legislation around building energy code reform the following key policy considerations should be discussed/addressed by legislators:

- Potential modification of the current calendar schedule for code reform proposals;
- Ensure the RAC has access to thorough and scientific technical and economic analysis of code changes; and
- Creating a review process for a uniform zero-energy code that municipalities can opt into.

Connection to Criteria

- **Meets a need established in the 2024 CAP to achieve GHG reduction goals** by supporting building code updates and building decarbonization.
- **Advances a cost-effective strategy recommendation that shows a net benefit to interested parties and/or the public.** Energy codes have long been shown as effective investments that provide savings to end users. Savings for building designers and builders also exist when adjacent states follow the same latest model code.
- **Demonstrates practice of similar policies in other states and jurisdictions,** as many other states advance and adopt buildings codes more regularly and inclusively than Pennsylvania and allow municipalities to adopt zero-energy codes.

Existing Examples

The International Code Council Codes creates model building codes to support governments with ensuring safe, and efficient standards. New Jersey and Virginia have both adopted updated building codes for commercial buildings and New Jersey has also adopted the latest residential building code[105]. Additionally, Maryland adopts the latest International Energy Conservation Code (IECC) codes by administrative rule, while Virginia has an online public process to gather broad input. These reforms help support more rapid code updates to meet the latest and most efficient standards.

Connections to Recommended Strategies

This recommendation connects most directly to the building strategies, specifically B1 which aims to develop improved building codes for new buildings and major retrofits to improve energy efficiency.

Enabling Community Solar

Ready for Advancement

Many Pennsylvania utility customers currently do not have access to solar because they rent, live in multi-tenant buildings, or have physical restrictions on their rooftops that make them unable to host a system. Community solar programs can help these utility customers access solar by allowing households and businesses within a geographic area to subscribe to and share electricity from a solar project. Utility customers that participate receive a credit on their electricity bill for the power produced by the project. This recommendation would authorize community solar in the Commonwealth.[106]

[105] "EnergyCodes" US DOE. 2024. https://www.energycodes.gov/infographics.
[106] Community choice aggregation- "allow[s] local governments to procure power on behalf of their residents, businesses, and municipal accounts from an alternative supplier while still receiving transmission and distribution service from their existing utility provider." Taken from https://www.epa.gov/green-power-markets/community-choice-aggregation.

Key Policy Considerations

Community solar in Pennsylvania could be authorized in a range of different ways, each offering a pathway which requires tradeoffs from existing policies. Policy considerations include:

- A change in the definitions of net metering to allow for net metering from remote generating facilities as well as allowing generation from one facility to be allocated to many customer accounts in amounts determined by that facility.
- Potential utility ownership of community solar projects and consumer rate structure in a deregulated marketplace.
- Impacts to customers who do not subscribe to community solar.
- Annual limits on the amount of community solar that can be interconnected each year.
- Incentives to increase low- and moderate-income participation.
- Requirements to use in-state labor.
- Site larger scale community solar projects on abandoned mine land, brownfields, large roofs, and low value agriculture land-which can be located near to distribution lines and is a more practical use case than grid-scale projects.

Connection to Criteria

- **Meets a need established in the 2024 CAP to achieve GHG reduction goals** since a net zero grid is foundational to achieving GHG emissions reduction goals.
- **Demonstrates practice of similar policies in other states and jurisdictions** as a range of other states have enacted legislation that enables community solar.
- **Introduces a new consideration or fills a gap left by existing and currently proposed legislation** since a range of bills have been proposed to enable community solar but none have yet been adopted in Pennsylvania over the last several years.
- **Meets needs communicated by interested parties**. The need for support of physical and policy infrastructure for solar energy sources at a community scale was during outreach for the CAEJC program. Many communities impacted by EJ concerns would benefit significantly from community solar both from an affordability and availability standpoint.
- **Leverages existing regional clean energy and other climate programs and policies.** Community Solar programs are often run in conjunction with and as part of existing state AEPSs.

Existing Examples

Community solar has been extremely popular in states where it has been implemented, including New York, New Jersey, Maryland, and Delaware. Many states' community solar legislation contains either requirements or incentives to drive policy goals. Most existing programs have been accomplished through tariffs that restrict the program to solar and limit the annual capacity of community solar. If community solar is accomplished through a change to net metering definitions, further definition would be required to limit the program to solar, limit the annual capacity if desired, and drive policy goals.

Connections to Recommended Strategies

This recommendation connects with strategy B5, regarding supporting distributed solar installations and additionally supports Strategy P1 for a net zero electricity grid.

Zero Emissions Vehicle Targets

Needs Further Development

Decarbonizing the transportation sector relies on increased adoption and use of ZEVs throughout the Commonwealth. Multiple ZEV technologies are currently available and will continue to develop as ZEV markets expand. This recommendation proposes setting targets for ZEV adoption throughout the Commonwealth and supporting vehicle markets as they move to decarbonize. Establishing goals for ZEV adoption will increase awareness of ZEVs and send a clear signal to consumers and vehicle manufacturers about the necessary trajectory of vehicle markets needed to reduce transportation emissions.

Key Policy Considerations

When developing legislation around ZEV adoption the following key policy considerations should be discussed/addressed by legislators:

- Amount and timing of an increase in electricity use and demand across the Commonwealth.
- ZEV targets as percentage of new LDV and MHDVs sales by 2035 and 2050.
- Consideration of the need for developing different sales targets for different MHDV vehicle classes.
- Specific technology adoption goals (battery electric vehicle [BEV], FCEV, etc.) vs technology neutral adoption goals.

This legislation should also include goals for charging/ZEV refueling infrastructure adoption throughout the Commonwealth and build from the Multi-State Medium and Heavy-Duty Zero Emissions Vehicle MOU[107] signed by Pennsylvania and range of other states.

Connection to Criteria

- **Meets a need established in the 2024 CAP to achieve GHG reduction goals** since net zero vehicles are foundational to achieving GHG emissions reduction goals.
- **Demonstrates practice of similar policies in other states and jurisdictions** as a range of other states have enacted legislation that aims to encourage ZEV adoption.
- **Meets needs communicated by interested parties**. Communities facing EJ issues identified mitigating existing sites and sources of air and water pollution as a priority climate strategy in outreach for the CAEJC program. Reducing ICE through ZEV adoption will help reduce air pollution, aligning with this strategy.

[107] Multi-State Medium and Heavy Duty Zero Emissions Vehicle Memorandum of Understanding. 2020. https://www.nescaum.org/documents/mhdv-zev-mou-20220329.pdf

Connections to Recommended Strategies

This recommendation connects most directly to the transportation strategies, specifically T2 and T3 which aim to support LDV electrification and MHDV decarbonization.

Existing Examples

Other states have passed ZEV goals and sales mandates through legislation. Michigan has a goal of putting two (2) million EVs on the road and making at least 50% of light-duty, and 20% of MHDVs sales electric in 2030. Additional Heavy-Duty Vehicle Standards have also been adopted across the country based on California's Advanced Clean Trucks (ACT) regulation. ACT requires manufacturers to achieve a set percentage of sales of medium- and heavy-duty ZEVs starting in 2024. Similar regulations have been adopted in ten states including Colorado, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Rhode Island, Vermont, and Washington State.

Low-Carbon Fuel Standard (LCFS)

Needs Further Development

The transportation sector accounted for over 24% of Pennsylvania's 2020 Net GHG emissions. A LCFS is a technology agnostic, market-based method to reduce GHG emissions in this sector by use of a credit market that incentivizes the use of lower-carbon fuels. These markets work by providing a baseline carbon intensity limit for fuels used in the state. Low-carbon fuels below the benchmark generate credits, while fuels above the carbon intensity benchmark generate deficits. Credits may be sold or traded. The compliance obligation is met by ensuring that the amount of credits earned or otherwise acquired from another party is equal to, or greater than, the deficits incurred. Much like renewable portfolio standards for the electricity sector, this incentivizes the least-cost achievement of the targeted carbon intensity baseline while allowing the market to pick the most appropriate decarbonization technology for a given use case.

Key Policy Considerations

A LCFS will require both enabling legislation and implementation regulations with an agency designated to lead the program administration. Specific areas of consideration include determining:

- The interaction of LCFS and ZEV, hydrogen, and CCS policies.
- If biogenic content testing of non-zero emission fuels should be required.
- If intrastate aviation fuel is part of the program.
- Whether to include maritime fuel as an opt-in.

Connection to Criteria

- **Meets a need established in the 2024 CAP to achieve GHG reduction goals** since net zero transportation is foundational to achieving GHG emissions reduction goals.
- **Demonstrates practice of similar policies in other states and jurisdictions** as several other states have established smoothly running LCFS programs.
- **Advances a cost-effective strategy recommendation** that shows a net benefit to interested parties and/or the public. The technology neutral, market-based approach costs little for the

state to implement and oversee and ensures GHG reductions take place at the lowest cost for a given target.

- **Leverages existing regional clean energy and other climate programs and policies**. LCFS programs can be compilatory to ZEV and hydrogen fuel programs which are generally considered eligible LCFS technologies.

Existing Examples

A LCFS was introduced in California in 2011, and similar standards have been passed in Oregon and Washington. More widely, the province of British Columbia and Canada has also implemented a LCFS.

Connections to Recommended Strategies

This recommendation connects most directly to the transportation strategies, specifically T3 which aims to support MHDV decarbonization, where low-carbon fuels will most likely be utilized. Additionally, this recommendation aligns with strategies supporting low-carbon fuels such as F2 regarding biomethane and C1 on hydrogen.

Pennsylvania Reliable Energy Sustainability Standard (PRESS)

Ready for Advancement

Twenty years ago, Pennsylvania led the nation by establishing the AEPS, which successfully promoted new and innovative forms of energy in the Commonwealth. Over the last two decades, Pennsylvania's energy standards have become outdated, and Pennsylvania has been surpassed by other states with more modern standards.

PRESS requires Pennsylvania to get 50% of its electricity from a diverse range of energy resources by 2035, including 35% from current and future clean energy sources, like solar, wind, small modular reactors, and fusion, 10% from sustainable sources like large hydropower and battery storage, and 5% from low emission forms of natural gas and other alternative fuels. PRESS aims to continue all the successful elements of AEPS but is also more inclusive to ensure diversity and reliability.

Key Policy Considerations

- Defining and delineating the types of energy included in each category.
- The eligibility of CHP systems in PRESS.
- Interaction with other state energy policies and energy resource needs of the region.
- Ability to support diverse and distributed energy systems within the current and future grid transmission, distribution, and interconnection construct.

Connection to Criteria

- **Meets a need established in the 2024 CAP to achieve GHG reduction goals** by establishing new benchmarks to advance Pennsylvania toward a Net Zero Grid.
- **Demonstrates practice of similar, successful policies in other states and jurisdictions** as several other states have implemented similar programs increasing the percentage of

alternative and renewable energy resources to supply energy to in-state customers.

- **Implements an all-the-above approach** to achieve climate and energy goals.

Existing Examples

Most of the Mid-Atlantic and Northeast states have similar renewable portfolio standards. The chart below shows the current and final requirements of the renewable portfolio standards of surrounding states with programs similar in design to Pennsylvania's AEPS.

Additionally, New Jersey has a 100% by 2050 goal and Maryland has a 100% by 2035 goal. These goals are non-binding but provide a roadmap and a target toward complete decarbonation of the state's power sectors.

Table 21. Alternative Energy Programs for Neighboring States

	Tier 1 Current	Solar Current	Tier 1 Max.	Solar Max.	Max Requirement Year
PA	8%	0.50%	8%	0.50%	2021
NJ	21%	5.50%	50%	1.1%*	2030
MD	27.20%	6.50%	35.50%	14.50%	2030
DE	24%	3.25%	40%	10%	2035
NY	8.2%	4%	70%	47%	2030
VA	10-23%	6%	100%	NA**	2050

*New Jersey has gone from a solar carve-out to the Successor Solar Incentive (Susi) program that consists of annual blocks paid fixed per MWH (megawatt hour) prices over 15 years.

**Virginia does not currently have state requirements for Tier 1 or Solar. The current production varies by utility producer which accounts for the range listed.

Connections to Recommended Strategies

This recommendation connects to strategy B5 (Onsite Solar), P1 (Net Zero Grid) and P2 (Distribution and Transmission Grids) by helping to support a reliable low-carbon grid.

Pennsylvania Climate Emissions Reduction Act (PACER)

Ready for Advancement

PACER is a cap-and-invest program that allows Pennsylvania to develop and implement an annual declining cap on the electric generation sector's CO_2 emissions. Through PACER, the DEP will be directed to run its own credit auction for carbon emissions independent of any other state. In addition to reducing climate emissions, the benefits of the PACER program will flow directly to Pennsylvanians. 70% of the program proceeds will go toward electric bill rebates for ratepayers. The remaining 30% will support projects that reduce air pollution in Pennsylvania; further lower costs on energy bills for low-income Pennsylvanians through a year-round LIHEAP program; and invest in new clean energy projects—such as CCS, geothermal deployment, and clean hydrogen—in energy communities that have previously hosted coal, oil, or gas infrastructure.

Key Policy Considerations

- The evaluation of the Pennsylvania Carbon Dioxide Budget Trading Program base budget, and its impact on jobs, consumers, and the environment.
- Interaction with other state and regional cap-and-trade initiatives and carbon markets.
- Determining the cap and how it might be reevaluated over time to ensure that the goals are being met.
- Price ceiling determination and implementation.

Connection to Criteria

- **Meets a need established in the 2024 CAP to achieve GHG reduction goals** since it will help to move toward a Net Zero Grid. The investments generated will be directed toward projects in the built environment and other strategies.
- **Demonstrates practice of similar policies in other states and jurisdictions** as several other states have implemented similar programs.
- **Advances a cost-effective strategy recommendation** that shows a net benefit to interested parties and/or the public.

Existing Examples

Several other states have state-level cap-and-invest or cap-and-trade programs. This includes California, Massachusetts, New York, and Washington. They are designed to better reflect the unique goals of their reflective locations.

For example, Massachusetts's Reducing CO_2 emissions from Electricity Generating Facilities sets annually declining limits for large in-state fossil fuel-powered power plants to ensure emissions reductions occur in Massachusetts on a path to full decarbonization in the electric sector by 2050. This program establishes an allowance trading program for CO_2 emissions from electricity generation, allowance auctions, limited allowance banking and "emergency deferred compliance." And sets a declining limit on aggregate CO_2 emissions from 24 large fossil fuel-fired power plants from 9.15 $MMTCO_2e$ in 2018, down to 1.8 $MMTCO_2e$ in 2050.

Connections to Recommended Strategies

This recommendation connects to strategy P1 (Net Zero Grid) and P2 (Distribution and Transmission Grids) by helping to support a reliable low-carbon grid.

Hydrogen Legislative Package

Needs Further Development

A range of benefits are associated with the expansion of low-carbon hydrogen technology. This recommendation would seek to review a full set of existing regulations and update or clarify them to provide better transparency and understanding to those seeking to deploy this technology in the Commonwealth.

Key Policy Considerations

As an emerging technology, hydrogen may not be adequately included in current regulations and incentives. Also, it may have areas of concern specific to its use and development that has not been legislated. Legislative discussion around this item is in the early stages. Additional research and discussion are needed on numerous areas, including:

- Incentives, regulations, and permitting for hydrogen infrastructure build out; and
- Relation and applicability of environmental regulations and approvals to hydrogen projects.

Ensuring this technology meets safety standards is vital, while additional clarity on how it fits into existing permitting and environmental regulations is critical to supporting project construction in a timely manner. This legislative package would aim to address those challenges. In addition to clarifications, it is also recommended that training or resources be made available to local permitting officials about this new legislative package to ensure local application of new regulations is understood.

Connection to Criteria

Meets a need established in the 2024 CAP to achieve GHG reduction goals by supporting and facilitating GHG reductions across sectors.

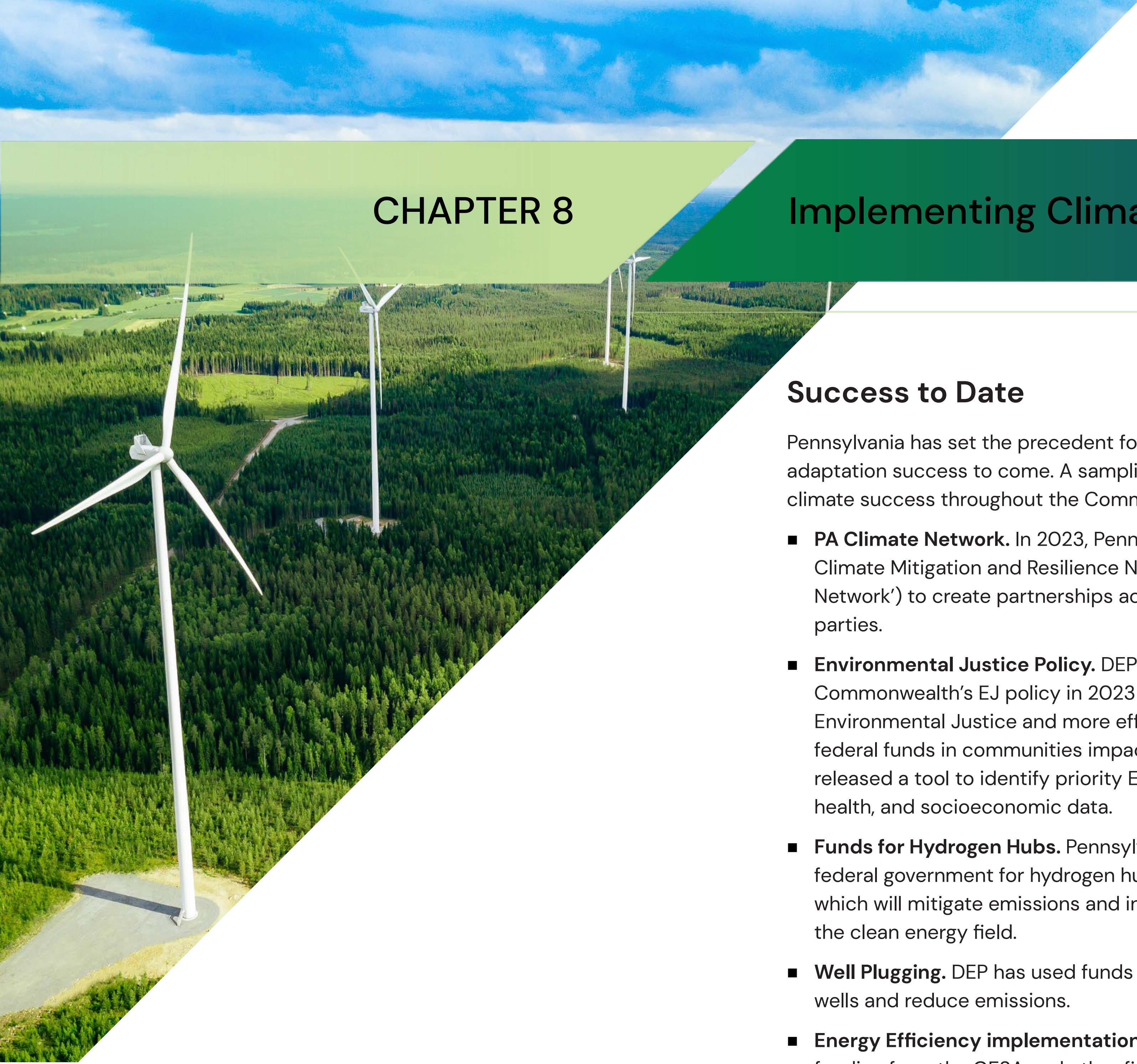
Introduces a new consideration or fills a gap left by existing and currently proposed legislation. As emerging fields and technologies, hydrogen is not fully incorporated into existing legislation and regulations.

Existing Examples

Utah enacted Code 79-6-106 in March of 2023, requiring the Utah Office of Energy Development's Department of Natural Resources to establish a Hydrogen Advisory Council (Council). The Council may promote research, develop resources, and engage with the public to facilitate the use of hydrogen; collaborate with stakeholders to create hydrogen development goals; identify funding opportunities for hydrogen projects; support the development of multiple hydrogen feedstocks; and review and recommend policies related to hydrogen deployment in Utah.

Connections to Recommended Strategies

This recommendation connects to Strategy C1 in the cross cutting technologies sector.



CHAPTER 8

Implementing Climate Action

Success to Date

Pennsylvania has set the precedent for further climate action and adaptation success to come. A sampling of prior and current climate success throughout the Commonwealth include:

- **PA Climate Network.** In 2023, Pennsylvania launched the Climate Mitigation and Resilience Network (or 'PA Climate Network') to create partnerships across groups of interested parties.
- **Environmental Justice Policy.** DEP updated the Commonwealth's EJ policy in 2023 to expand the Office of Environmental Justice and more efficiently prioritize the use of federal funds in communities impacted by EJ issues. DEP also released a tool to identify priority EJ areas using environmental, health, and socioeconomic data.
- **Funds for Hydrogen Hubs.** Pennsylvania won funds from the federal government for hydrogen hubs MACH2 and ARCH2, which will mitigate emissions and increase job opportunities in the clean energy field.
- **Well Plugging.** DEP has used funds from the IIJA to plug orphan wells and reduce emissions.
- **Energy Efficiency implementation.** Pennsylvania has used funding from the GESA and other financing mechanisms.

- **Conservation Landscapes.** Eight large regions, known as conservation landscapes, use state parks and forests as a foundation for activities to foster community engagement in sustainability, conservation, and recreation projects. These areas host strategic investments for State agencies and statewide partners.
- **Sea Level Rise Data Production.** Pennsylvania, through the Delaware River Basin Commission, identified water resources vulnerability to sea level rise in 2022 and created a tool to project extreme precipitation to support stormwater management and infrastructure design in 2024.
- **Citizen Hazard Preparedness Guide.** In 2021, PEMA updated guidance to help citizens plan and prepare for hazards such as flood, fire, and winter storms.
- **Community and Watershed Forestry Funds.** Each year, DCNR offers funding for projects that, among other things, increase tree canopy and reduce flooding through stream rehabilitation.

Equitable and Beneficial Implementation

DEP favors an implementation approach that is designed to equitably and beneficially improve the lives of Pennsylvanians. Both the benefits and costs of implementing the CAP should be equitably distributed so as to maximally improve the lives of everyone, and to avoid unfairly burdening certain communities 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. The following sections discuss additional considerations to support equitable and beneficial implementation.

Inclusive & Equitable Processes

Equitable and beneficial implementation of this CAP relies not only on achieving outcomes that improve equity and EJ but also on conducting implementation processes in an inclusive and equitable way. To do this, DEP will focus on proactive community engagement and enhanced public participation. DEP will be engaging directly with communities, particularly those in EJ areas to provide support, assess challenges, and capture opportunities throughout climate mitigation and adaptation efforts.

Proactively engaging with communities may involve making use of existing convening points and improving access engagement where needed and possible. Community outreach tactics used in the implementation of this CAP will likely include:

- Individual partner outreach,
- Partner events such as community meetings,
- DEP/Office of Environmental Justice events,
- Educational forums, and
- Developing and implementing a communications strategy.

Additionally, as community engagement is a part of numerous funding opportunities that could support CAP actions, DEP will aim to be strategic about multiple engagements and strive to combine efforts where reasonable to avoid engagement fatigue. Overall, throughout its climate initiatives DEP aims to engage in public involvement that integrates the stated needs and concerns of communities facing EJ issues.

Acknowledge Historical & Local Context

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.[108] 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.

DEP acknowledges that historically and currently, low-income, and low-wealth communities and communities of color bear a disproportionate share of detrimental environmental impacts with accompanying adverse health impacts. This disproportionate impact, generated by multiple factors, often makes EJ areas most vulnerable to the negative impacts of climate change.

Equitable and beneficial implementation of this CAP will strive to acknowledge this context and will aim to redress injustices resulting from the historical legacy of redlining and structural racism.

Centering community voices and listening to the unique needs and local context of all communities, not just those in EJ areas, will also be crucial to ensuring equitable and beneficial implementation of CAP strategies.

Distribution of Benefits & Impacts

A goal of equitable and beneficial implementation is to provide the greatest benefits to the most in-need communities and to reduce climate impacts and risks on the most vulnerable communities. Additionally, though EJ areas may be most vulnerable to climate impacts, they often contribute least to the emissions that contribute to climate risks. As a result, equitable and beneficial implementation will aim to minimize undue financial burden on communities in addressing climate risks not of their own making.

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 monitoring and evaluation (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

[108] 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.)]. US Global Change Research Program, Washington, DC, pp. 438–478. doi: 10.7930/NCA4.2018.CH11.

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.

Additionally, equitable and beneficial implementation of this CAP will aim to prioritize implementing strategies and actions based on community input and concerns and focus on addressing the greatest areas of concern for low-wealth and minoritized communities. As there are numerous types of benefits that can be provided by climate action (emissions reduction, energy cost savings, improved transit access, criteria pollutant reduction, reduced climate risk, etc.), tools such as multi-criteria analysis (CIP, HMP, etc.) may be useful to better understand and prioritize implementing strategy actions.

Mechanisms for Accountability

To help support accountability in the implementation of this CAP, a clear framework for metrics and communication of progress is advised to keep the public and interested parties informed. Numerous metric options have been implemented by other parties and could be reviewed when selecting the most optimal approach for DEP.

Additionally, it is important to acknowledge that tradeoffs will be involved in implementation efforts for this CAP, particularly due to the number of sectors, interested parties, and complexities that will be involved in the variety of strategies involved in this CAP. Funding to support implementation efforts is also finite. As a result, it will be important to be transparent in the implementation process to maximize accountability. Transparency will help communicate key successes along with potential setbacks and can provide understanding around situations when certain actions may not be able to be taken.

Addressing Health

Many energy-related activities that produce high levels of CO_2 emissions also produce high levels of local air and water pollutants, which have direct and immediate impacts on polluted areas. Strategies to address energy-related sources of CO_2 emissions, such as electric power generation, transportation, and industrial use, will likely yield substantial co-benefits in the form of improved air and water quality. The potential for these co-benefits is well documented. In some cases, the social value of these co-benefits (in terms of improved health and reduced premature mortality) may actually be larger than the climate-related benefits of decarbonizing the energy sector.[109,110]

Additionally, energy efficiency improvements can be highly connected to health improvements, especially in poor areas with dilapidated buildings. Implementation efforts could aim to address both climate impacts of the buildings sector and improve health outcomes through a coordinated use of healthcare dollars (e.g. Medicaid) to support energy efficiency improvements for which there could be a clear link with health outcomes.

[109] Yang, Hui, An Thu Pham, Joel Reid Landry, Seth Adam Blumsack, and Wei Peng. 2021. "Emissions and Health Implications of Pennsylvania's Entry into the Regional Greenhouse Gas Initiative." Environmental Science & Technology 55 (18): 12153–61. https://doi.org/10.1021/acs.est.1c02797.

[110] Choma, Ernani F., John S. Evans, James K. Hammitt, José A. Gómez-Ibáñez, and John D. Spengler. 2020. "Assessing the Health Impacts of Electric Vehicles through Air Pollution in the United States." Environment International 144 (November):106015. https://doi.org/10.1016/j.envint.2020.106015.

Impacts to Energy Rates

The energy rate analysis evaluates the impact on consumer costs for electricity and natural gas. The analysis considers the average statewide impact on energy rates and customer bills. The analysis is based in whole or in part on a large body of forward-looking assumptions and provides a high-level analysis of a complex topic. Results from this analysis rely on the implementation of all strategies and do not consider any changes to regulatory structure, or changes to evolving supply and demand dynamics of energy markets. Results should be used to understand overall potential trajectory of change for energy rates, and not as projections.

Gas Rates

The following discussion focuses on residential gas customers as a representative group to illustrate the impacts of gas rate changes. In the Baseline BAU scenario, characterized by relatively stable gas demand and commodity prices, the residential gas rate remains fairly steady, rising slightly from $13.54 per MMBtu in 2020 to $15.05 per MMBtu in 2050.

As shown in Figure 24, the residential retail gas rate rises significantly in the Strategy scenario, from $13.54 per MMBtu in 2020 to $26.22 per MMBtu in 2050, representing a 94% increase in real terms. This increase is attributed to higher unit costs of gas supply and utility delivery services:

- The higher unit **cost of gas supply** is driven by higher-priced gas, as biomethane supplies 26% of residential gas demand and costs $29.4 per MMBtu by 2050. With the remaining 74% of residential gas demand continuing to be served by conventional natural gas, the weighted average commodity cost increases from $3.7 per MMBtu in 2020 to $9.8 per MMBtu in 2050 in real terms.
- The higher unit **cost of utility service** is driven by a roughly 40% decline in residential gas throughput, coupled with smaller reductions in utility costs. This means that the utility costs for delivery service are spread over fewer units of gas. It is worth noting that despite a decrease in gas throughput and the number of gas customers, reducing utility costs significantly in the short term may be challenging. This is because the utility will need to maintain spending to ensure the reliability and integrity of the majority gas infrastructure for the customers who continue to rely on it and are spread across the distribution system.

Figure 24 Residential Gas Rate in the Baseline BAU

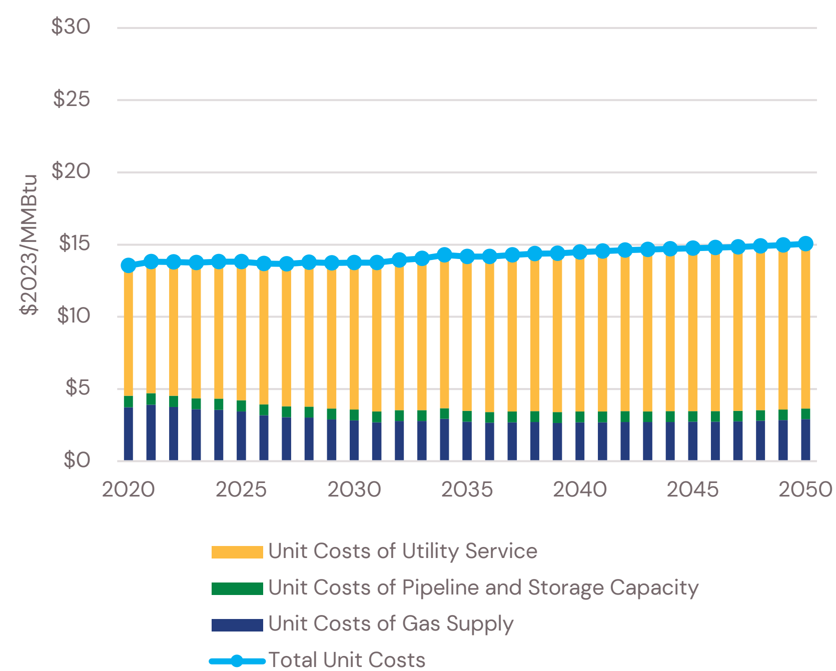
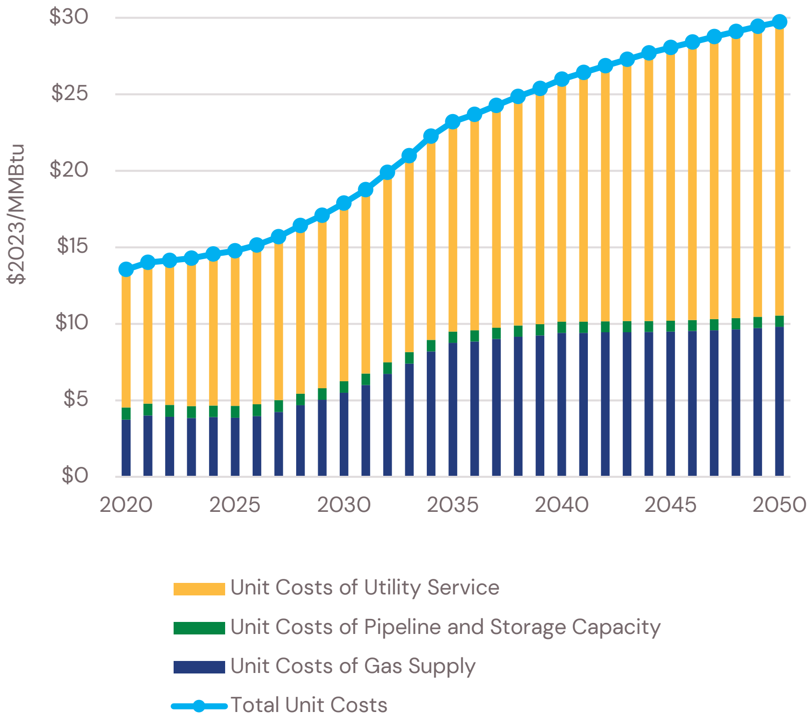


Figure 25. Residential Gas Rates in the Strategy Scenario



Similar to the trend in residential gas rate, in the Baseline BAU scenario, annual residential gas bills remain steady over the study period, increasing slightly from $1,073 in 2020 to $1,090 in 2050. In the Strategy scenario, these bills rise from $1,073 to $1,926, an 80% increase. This growth is less than the 94% rise in gas rates, due to the moderate reduction in the use of gas per customer, benefiting from efficiency gains derived from equipment upgrades and improvements in building envelopes. It is crucial to note that these figures represent averages. Some customers, especially those who adopt extensive energy efficiency measures or reside in newer homes, will consume considerably less gas and therefore be less affected by the rate hikes. Conversely, customers with less efficient appliances and higher levels of gas consumption will feel a more pronounced impact from the rate increases.

It is important to note that this indicative analysis relies on a number of high-level assumptions that significantly influence overall model outcomes. Some limitations and uncertainties include:

- Considerable uncertainty regarding how evolving supply and demand dynamics within decarbonization pathways might alter the costs associated with low-carbon fuels compared to current forecasts.
- Significant uncertainty about how much cost savings in utility spending (CapEx and OpEx) can be achieved in pathways that result in significant declines in gas throughput and gas customer numbers.
- It would seem unlikely that no regulatory changes for gas utilities would be implemented in a scenario with a roughly 40% decline in residential gas customers and/or throughput.
  - Regulatory options and strategies, such as targeted electrification, accelerated depreciation, rate re-design, external funding, hybrid heating, and utility spending reductions, can be investigated in the future to mitigate the rate and bill impacts of decarbonization pathways.
- Rate increases in the Strategy scenario also need to be considered in the context of costs involved in other options to pursue deep emission reductions.

To better understand potential gas rate impacts and address the uncertainties, future studies focusing on gas rate impacts in more detail should ideally collaborate with the Commonwealth's gas utilities or obtain additional utility data, to better inform the potential for cost reductions in different scenarios. This collaborative effort would facilitate a more precise understanding of how various decarbonization pathways influence utility expenditures and contribute to more accurate gas rate forecasts.

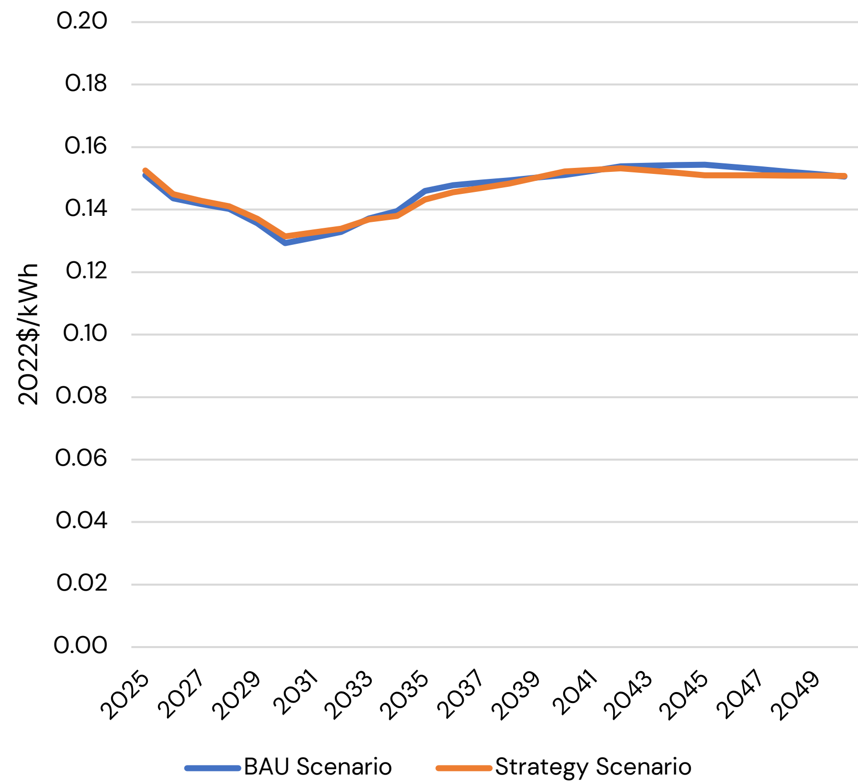
Electricity rates

Similar to the gas rate, electricity rates were considered for the BAU and Strategy scenario. The analysis focused on the average rate impact across all consumers in the Commonwealth. Under the BAU and the Strategy scenarios overall rates on a unitary basis were very similar. That is, the combined costs of generation, transmission, and distribution needed to serve load in BAU conditions versus those used in the Strategy scenario resulted in a very similar rate of roughly 15 cents per kWh in 2022$ with some variance over the time period, but fairly flat into the long-term.

In contrast, the total costs to serve load increase between the BAU and Strategy scenarios.

- The electric supply costs in this analysis are highly dependent on the ability to access federal subsidies and incentives for clean energy technology.
- The efficiency of new appliances is a large driver in limiting load growth in the Strategy scenario. Adoption of efficient space heating and cooling measures and phasing out of less efficient sources such as resistance heating is critical to managing load growth.
- The load growth further impacts the bulk and distribution sector infrastructure needs. In the Strategy scenario, overall energy demand for electricity in Pennsylvania is expected to decrease, but the consumption pattern changes, which drives much of the difference in the power system needs and forward costs.

Figure 26. Projected Average Electricity Rate Pennsylvania



Creating Jobs and Economic Opportunity

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, Asians, African Americans, and veterans were all employed at greater rates than statewide demographic averages.[111]

Growth in clean energy jobs could assist the "just transition"—a shift from a fossil-based economy to a clean energy economy.

Encourage The Growth of Clean Energy Industries & Manufacturing In PA

The actions in this CAP aim to support the development of clean energy industries and manufacturing in Pennsylvania, such as hydrogen, solar, wind and CCUS efforts. Investing in renewable and clean energy technologies will help create new jobs and economic opportunities for Pennsylvanians. Setting up PA as a leader in this emerging market will support long-term economic growth for the state, and provide strong, stable job opportunities.

Transitioning Energy Communities

As an energy producing state, Pennsylvania has a significant workforce involved in mining and energy work that will be heavily impacted in the transition to a low-carbon economy. Supporting these energy communities through creating good paying jobs and other programs for increasing their participation in the new clean energy workforce should be prioritized. 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. Opportunities such as adding solar generation facilities to abandoned coal mine lands could be promising and should be further evaluated and prioritized.

Where possible, implementation efforts can aim to leverage existing resources to foster new economic growth – both labor expertise from mining and extractive industries as well as the unique geographic or locational situations that may be created through unused (abandoned) mining or industrial land.

Maximizing Co-Benefits

Climate action has many benefits beyond just reducing emissions. When supporting implementation of the strategies in this plan, DEP aims to maximize the associated economic, environmental, health, and social co-benefits of these climate actions.

Economic

Climate action initiatives can stimulate economic growth in a variety of ways, including fostering innovation in renewable energy and clean technologies, creating new job opportunities, and saving public money and costs to residents by adapting to climate risks before they happen.

Energy efficiency retrofits, for example, reduce costs for businesses and households by alleviating their energy burden (the percent of their income spent on energy bills), and simultaneously create jobs to design, produce, install, and maintain energy-efficient equipment and appliances. Measures in this CAP target increased workforce participation in PA broadly, but with a particular emphasis on bringing in jobs to EJ and energy communities.

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[111] "2020 Pennsylvania Clean Energy Employment Report." DEP Programs Office. 2020. https://files.dep.state.pa.us/Energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/2020EnergyReport/2020_PACEIR_FINAL_1.1.pdf.

Additionally, climate resilience measures, such as infrastructure improvements, can mitigate the economic impacts of extreme weather events and natural disasters, effectively saving public money and costs to residents Climate resilience measures, such as infrastructure improvements, can also mitigate the economic impacts of extreme weather events and natural disasters.

Environmental

Climate actions contribute to various environmental benefits, beyond simply emissions reductions. Conservation measures, such as reforestation and sustainable land use practices, help preserve vital ecosystems, providing habitats for diverse plant and animal species. Other actions such as sustainable agricultural practices and responsible water management enhance resilience to climate change, safeguarding ecosystems and the services they provide to communities. This CAP aims to prioritize actions that contain environmental benefits, in addition to health, economic, and equity benefits.

Health

Climate mitigation actions, such as energy efficiency retrofits and clean energy development reduce the use of combustion fuels on site in homes, businesses, and power plants and will have localized indoor and outdoor air quality benefits (e.g., reduced emissions of PM2.5, CO, SO_2, and NO_X). Air quality improvements may lead to a reduction in the number of cases of bronchitis, asthma, heart attacks, and other adverse health conditions.[112]

Climate adaptation efforts can also reduce illness and health risks by implementing strategies that address the health impacts of climate change. For example, improved urban planning and infrastructure can mitigate extreme heat events, reducing the risk of heat-related illnesses. Similarly, disaster preparedness measures can enhance resilience to extreme weather events, minimizing health hazards from floods and storms.

Social: Environmental Justice and Equity

The mitigation and adaptation strategies are both informed by and meant to contribute to EJ and equity. Social impacts are directly related to economic, environmental, and health impacts. Therefore, by approaching each area equitably, outcomes should have a positive social impact on those experiencing the most negative outcomes of and contributors to climate change.

Interested Parties

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

[112] "Progress Cleaning the Air and Improving People's Health." Reports and Assessments. US EPA, OAR. June 8, 2015. https://www.epa.gov/clean-air-act-overview/progress-cleaning-air-and-improving-peoples-health.

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 and 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 in 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.

Community-based organizations (CBOs): CBOs provide a vital link between the creation of programs and policies and their successful implementation across the Commonwealth. CBOs should be involved in the early planning stages of programs to foster collaborative, sustainable relationships, particularly between state and local governments and the communities impacted by the proposed actions in this CAP. Also, CBOs often represent the interests of low-wealth and minoritized communities, who are often underrepresented in policy decision-making even when those decisions have an outsized impact on their communities. To maximize the benefits of climate action, these communities facing EJ issues should have the opportunity to not only advocate for their needs but also contribute to climate solutions. Overall, CBOs provide crucial insight into both the needs and strengths of their communities which both increase public by-in while also improving program outcomes for all Pennsylvanians.

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 Utility 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 implementers 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 co-creation 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. More comprehensive updates to the municipal planning code have the potential to affect climate mitigation and adaptation of the built environment.

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.

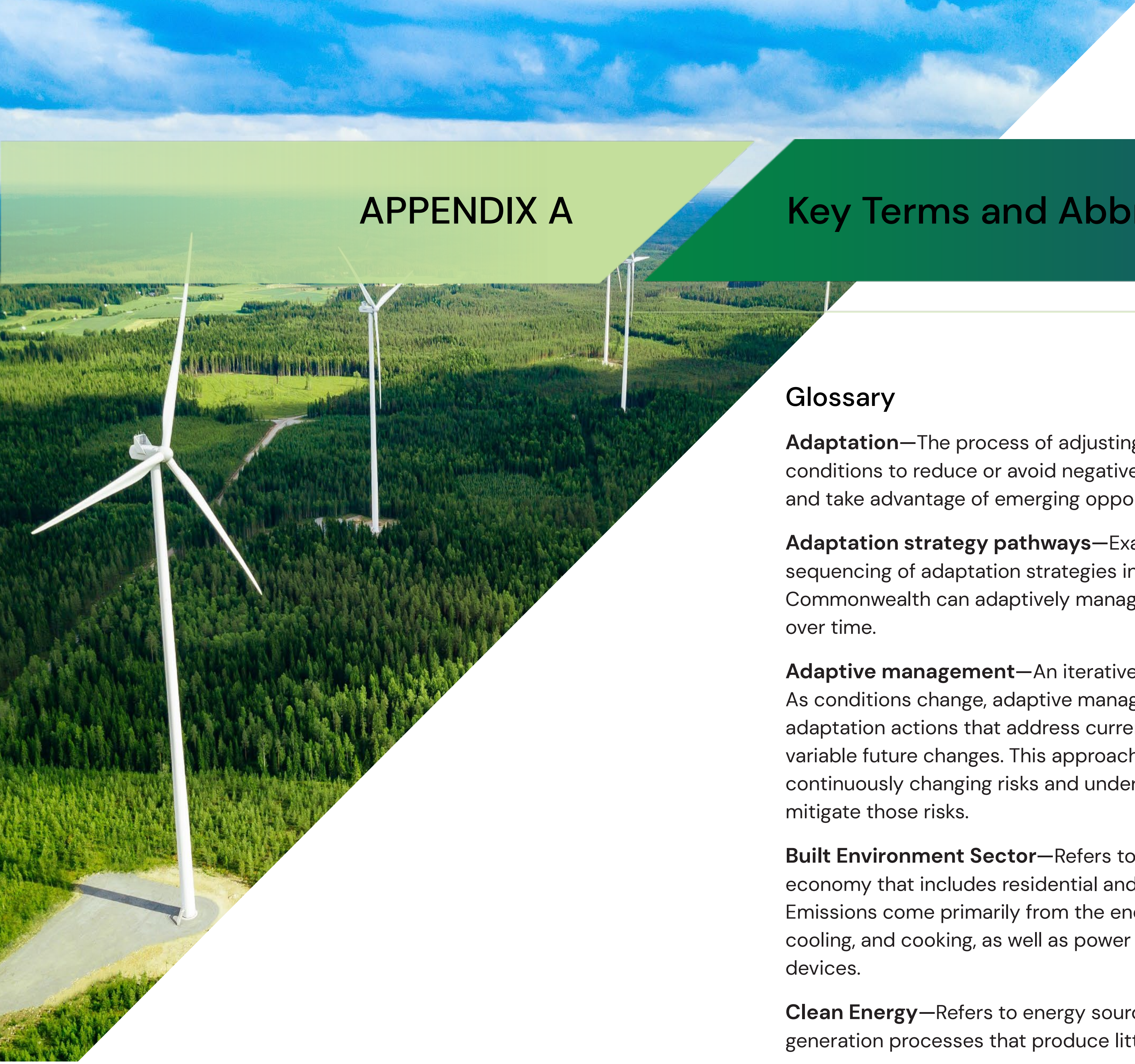
Federal government: Although the Commonwealth can implement many programs and policies, the federal government through its programs, funding, rules, and laws has outsized influence over all national emissions sectors. Federal funding and legislation can reduce emissions rapidly and expand climate resilience strategies.

Monitoring Progress

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 has to 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 and Abbreviations

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.

Built Environment Sector—Refers to the sector of Pennsylvania's economy that includes residential and commercial buildings. Emissions come primarily from the energy used in the heating, cooling, and cooking, as well as power for lighting and electronic devices.

Clean Energy—Refers to energy sources, technologies, or generation processes that produce little to no GHG emissions and have improved environmental impacts on water and air quality compared to traditional fossil fuels.

Community Solar—Solar installations that are smaller than utility scale but serve multiple households within a geographic area, by allowing them to subscribe to and share electricity from the installation.

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— A geographic area characterized by increased pollution burden, and sensitive or vulnerable populations based on demographic and environmental data. As referred to within this policy, this term identifies the geographic location where DEP's EJ Policy applies.

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.

Environmental Justice (EJ) - Environmental justice means the just treatment and meaningful involvement of all people, regardless of income, wealth, race, color, national origin, area of residence, Tribal affiliation, or disability, in agency decision-making and other activities that affect human health and the environment so that people: are fully protected from disproportionate and adverse human health and environmental effects (including risks) and hazards, including those related to climate change, the cumulative impacts of environmental and other burdens, and the legacy of racism or other structural or systemic barriers; and have equitable access to a healthy, sustainable, and resilient environment in which to live, play, work, learn, grow, worship, and engage in cultural and subsistence practices. It further involves the prevention of future environmental injustice, and the redress of historic environmental injustice, and the centering of environmentally burdened community voices in addressing environmental justice concerns.

Exposed areas—Geographic areas projected to be affected by climate change based on climate change projections.

Fuel and Gas Systems Sector—Refers to the sector of Pennsylvania's economy that encompasses the upstream delivery of fuels to non-electricity generation end-use points.

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).

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_2O), and fluorinated gases.

GHG reductions—Reducing the emissions of heat-trapping greenhouse gases into the atmosphere.

Impacts—Refers to the effects of a climate hazard, e.g., potential impacts of warmer temperatures include health risks on hot days.

Industrial Sector—Refers to the sector of Pennsylvania's economy that manufactures and processes chemical and physical materials.

Job-year—One year of work for one person. For example, a new construction job that lasts five years is five job-years.

Land Use and Agriculture Sector—Refers to the sector of Pennsylvania's economy that include agricultural lands and 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.

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."[113] Environmental justice areas are used in this assessment as a proxy for locations where populations are already overburdened by hazards and other structural disadvantages.

Power Generation Sector—Refers to the sector of the economy of Pennsylvania that includes power generation, transmission, and distribution.

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).

Transportation Sector—Refers to the sector of Pennsylvania's economy that includes activities to facilitate the conveyance of people and goods. Emissions are primarily from the burning of fuel to power the internal combustion engines of light-duty passenger cars and trucks.

Vulnerable populations—Populations more likely to experience adverse impacts from exposure to climate hazards because of demographics factors (e.g., race, gender), socioeconomic status, and life- or livelihood-sustaining needs (e.g., dependence on electricity for critical medical care).

Waste Sector—Refers to the sector of Pennsylvania's economy that includes the collection, transportation, processing, and disposal of waste.

[113] "EJ 2020 Glossary." US EPA. 2020. https://19january2021snapshot.epa.gov/environmentaljustice/ej-2020-glossary_.html#:~:text=Environmental%20Justice%20(EJ)%20%2D%20The,laws%2C%20regulations%2C%20and%20policies.

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
BIL	Bipartisan Infrastructure Law or the *Infrastructure Investment and Jobs Act* of 2021
BMP	Best management practices
BTU	British thermal units
BRIC	Building Resilient Infrastructure and Communities
CBO	Community-based organization
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
CDFI	Community Development Financial Institutions
CGE	Computable general equilibrium
CHP	Combined heat and power
CIP	Capital Improvement(s) Plan or Program
CRP	Carbon Reduction Program
CRS	Carbon Reduction Strategy
CSO	Combined sewer overflow
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
EE&C	Energy efficiency and conservation
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	US Department of Housing
HVAC	Heating, ventilation, and air conditioning
IA	Impacts assessment
ICE	Internal combustion engine

IEA	International Energy Agency
IECC	International Energy Conservation Code
IgCC	International Green Construction Code
IPM	Integrated Planning Model
IRA	*Inflation Reduction Act* of 2022
LCFS	Low-Carbon Fuels Standard
LDV	Light-duty vehicle
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
PDA	Pennsylvania Department of Agriculture
PEA	Philadelphia Energy Authority
PEDA	Pennsylvania Energy Development Authority
PEMA	Pennsylvania Emergency Management Agency
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
RNG	Renewable natural gas
SCC	Social cost of carbon
SEDS	State Energy Data System
SEFI	State Energy Financing Institution
SIT	State Inventory Tool
SLR	Subsequent License Renewal
SREC	Solar renewable energy credits
SWE	Statewide Evaluator
USDA	US 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

This methodology section covers the methods employed to determine quantitative results in four areas of this report:

- Business-As-Usual Methodology
- GHG Reduction Strategy Methodology
- Energy Rate Methodology
- Economic Modeling Methodology

The BAU methodology informs the GHG inventory and emissions projections based on current policies and conditions out to 2050 that is included in CHAPTER 3 Greenhouse Gas Emissions.

The GHG reductions strategy methodology informs the quantitative results of each strategy included in CHAPTER 4 Greenhouse Gas Reduction Opportunities of this CAP in terms of emissions reductions and costs. A summary of those quantitative results can be found in the key metrics box for each strategy.

The energy rate methodology informs the analysis of how the implementation of these GHG reduction strategies will impact energy markets and the cost of power to the Commonwealth.

The economic modeling methodology informs the broader economic implications presented within each strategy and to the Commonwealth including employment, DPI, and GSP.

BAU Methodology

For this CAP, two BAU scenarios were developed to understand how Pennsylvania's GHG emissions could look in the future. The baseline BAU scenario reflects only the current policies being held consistent with no new policies to reduce GHG emissions; the reference BAU is a more probable scenario that incorporates federal policies such as the IRA and IIJA into emissions projections. These BAU scenarios use identical historical data and begin to diverge in the baseline year of 2021. For each BAU scenario net emissions, including both sources of emissions and emission sequestered from land use and carbon sinks are presented in CHAPTER 3 Greenhouse Gas Emissions. The key differences between the reference and baseline BAU scenarios include decreased emissions from electricity use in residential and commercial buildings, lower transportation emissions from a more aggressive transition to EVs, smaller increases in projected industrial emissions due to improved efficiency, and lower-carbon intensity from power sector emissions.

The BAUs were developed through a series of steps that mostly align with the BAU approach ICF used for the 2021 and 2018 Pennsylvania CAP update and the Energy Assessment Reports. 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 EIA SEDS, the Environmental Protection Agency 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 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 prior plans and allows 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 scenarios 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 time series. 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 baseline BAU scenarios project what emissions in Pennsylvania would be through 2050 if only the existing (Pre-IRA/IIJA) GHG reduction policies and programs continue. This includes policies that have been in place for several years. The policies included in the BAU are:

- **Act 129.** Act 129 requires Pennsylvania's seven largest 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.
- **HFC Phaseout.** Pennsylvania will phase out HFCs in accordance with EO 2019-01 and the AIM Act.
- Policies included in the **2022 AEO Reference Case**[114].

The reference BAU scenarios considers all the policies above along with the following.

- **Inflation Reduction Act.** The IRA includes investments across sectors to reduce emissions in line with the United States' emissions reduction goals. This includes reduced power sector emissions, increased EV penetration, building and industry energy efficiency and electrification, among many other programs.
- **Infrastructure Investment and Jobs Act.** The IIJA includes federal programs investing in improved infrastructure, many of the programs stemming from the IIJA have a goal of reducing emissions across sectors that will be reflected in changes in Pennsylvania emissions.

Sector Approach and Data Sources

The following sections outline the approaches and accompanying data sources used 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

[114] "Annual Energy Outlook." US EIA. 2022. https://www.eia.gov/outlooks/aeo/assumptions/pdf/summary.pdf.

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 AIM act aligned with the Kigali Amendment that requires GHG emissions reductions of 26% below 2005 levels by 2025 and 80% below 2005 levels by 2050.

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 VOCs.[115] 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 United States GHG Inventory) and EIA.

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.

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, 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.

[115] 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.pa.gov/agencies/dep/programs-and-services/air/methane-reduction-strategy.html.

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

CO_2 Sight is a strategic planning platform for decarbonization developed and maintained by ICF. This platform leverages ICF's experience developing energy and climate policies and programs into a unified scenario analysis that allows users to assess future scenarios. The platform allows for high customization based on individual project needs.

Strategy B1. Building Codes

Methods, Data, and Key Assumptions

Residential Energy Savings

Using ICF's Energy Code Calculator,[116] the analysis team assumed an IECC 2018 base code and then implemented projected future IECC code versions every six years (starting with IECC in 2024) through 2050. The analysis team also reviewed the 2024 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 2018 codes in Pennsylvania.[117] 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.[118] New home projections were provided by US Census growth rates.[119] This approach delivers both electricity and natural gas savings.

Commercial Energy Savings

Using ICF's Code Calculator, the team assumed an American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 2016 base code and implement projected future ASHRAE code versions every six years through 2050. The team assumes 90% code compliance for all new construction,

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

[117] 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.

[118] 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.

[119] National, State, and County Housing Unit Totals: 2020-2022 (census.gov) https://www.census.gov/data/tables/time-series/demo/popest/2020s-total-housing-units.html.

renovations, and additions with a 30-year measure life. This approach delivers both electricity and natural gas savings.

GHG Emission Factors

GHG emission reductions are included in Strategy P1. ICF calculated a blended gas supply emission factor over time based on the available supply of renewable natural gas (see Fuel Supply Biomethane strategy for more details) and overall gas demand across the state. Other fuel emission factors come from the US Inventory and 2006 IPCC Guidelines for National Greenhouse Gas Inventories (consistent with the SIT).

Cost Methodology

Cost per square feet was used for both Residential and Commercial buildings. Cost increase compared to baseline commercial buildings were based on the per square foot ASHRAE Standard 90.1-2019 (ASHRAE 2019) edition[120] from Standard 90.1-2016 and set at $1.29/sq ft taken from energy codes.gov for Pennsylvania.

Cost increases compared to baseline for residential buildings was take from energy codes.gov[121] and included a cost increase per unit single family $4,169/unit average and a cost increase per unit multifamily $1,583/unit average. Energy costs savings were derived by multiplying energy changes by AEO's utility rate projections for electricity, natural gas, and fuel oil.

[120] Cost Effectiveness Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Pennsylvania. 2021. https://www.energycodes.gov/sites/default/files/2021-07/Cost-effectiveness_of_ASHRAE_Standard_90-1-2019-Pennsylvania.pdf.

Strategy B2. Electricity Efficiency in Buildings, B3. Gas Efficiency in Buildings, B4. Building Electrification

Methods, Data, and Key Assumptions

The building approach for B2, B3, and B4 utilizes CO_2Sight's building tool, which provides energy change and emissions change information through its DER Planner tool.

Building energy use and building emission projections are based on energy consumption from electricity, natural gas, fuel oil, and propane in existing residential (single-family, multifamily, and mobile homes) and commercial buildings (office, food service, school, hotel, healthcare, retail, and warehouse). The base year and projections for energy consumption in existing buildings are built from the Baseline BAU for buildings. Data from 2022 AEO, which represented projected energy user prior to the passage of the IRA, from the US EIA[122] was scaled to AEO census level data with the ResStock and ComStock building models of North American building stock with county-level resolution. The tool first calibrates ComStock and ResStock energy consumption to AEO energy consumption on a census division level. It then proportionally adjusts county-level energy consumption to the scaled census division level. Energy use values have been integrated with emissions factors for primary fuels (electricity, gas, propane, and fuel oil) to provide total emissions.

[121] Cost-Effectiveness of the 2021 IECC for Residential Buildings in Pennsylvania. 2021. https://www.energycodes.gov/sites/default/files/2021-07/PennsylvaniaResidentialCostEffectiveness_2021.pdf.
[122] "Annual Energy Outlook." US EIA. 2023. https://www.eia.gov/outlooks/aeo/index.php.

Calculating Energy Change

DER Planner is a bottom-up model that is built upon the best practice principles for potential modeling outlined by the National Action Plan for Energy Efficiency in their Guide for Conducting Energy Efficiency Potential Studies.[123] The model can be used to calculate technical, economic, and achievable potential estimates. Together, the CO_2Sight platform and DER Planner estimate energy and emissions changes from a range of decarbonization strategies, including electrification retrofits and energy efficiency.

Building characteristics and energy use data for modeling buildings are derived from ResStock[124] and ComStock[125] datasets provided by the National Renewable Energy Laboratory (NREL). These datasets integrate large public and private data sources statistical sampling, detailed sub-hourly building simulations, and high-performance computing. By synthesizing multiple sources into a single resource, these data allow for a granular understanding of the housing and commercial stock and the impacts of building technologies in different communities and businesses. These data are comprehensive and widely used across similar analyses and modeling efforts, and thus allow for the development of comparable results. The ResStock and ComStock energy use data are calibrated to match the EIA's AEO dataset.

This tool allows the analysis of over 80 residential and commercial measures in selected regions applied to the Pennsylvania building characteristics. The model uses key inputs such as equipment stock, participation rate curves, and energy change per measure and estimates potential savings from applying efficient measures available for each building type and end-use. Given the efficient technologies available, this quantifies how much energy could be reduced. To compute total savings potential, the model runs all permutations combining savings per EE measure unit, expected measure penetration, and total number of measure units (or total eligible stock) by all adoption types (ROB and RET).[126] By integrating DER Planner and comprehensive datasets such as ResStock and ComStock, CO_2Sight aggregates energy and emissions changes to estimate changes in energy use. ICF's program experience and available national data sources inform these measures' impacts on energy use.

GHG Emission Factors

GHG emission reductions for electricity are included in strategy P1. ICF calculated a blended gas supply emission factor over time based on the available supply of renewable natural gas (see Fuel Supply Biomethane strategy for more details) and overall gas demand across the state. Other fuel emission factors come from the US Inventory and 2006 IPCC Guidelines for National Greenhouse Gas Inventories (consistent with the SIT).

DER Planner Inputs

DER Planner employs a systematic approach to estimate energy savings profiles for the portfolio of measures representing various policy scenarios. This involves leveraging inputs such as equipment

[123] National Action Plan for Energy Efficiency "Guideline for Conducting Energy Efficiency Potential Studies." 2015. https://www.epa.gov/sites/production/files/2015-08/documents/potential_guide_0.pdf

[124] "ResStock Analysis Tool." NREL. n.d. https://www.nrel.gov/buildings/resstock.html.

[125] "ComStock." NREL. n.d. https://comstock.nrel.gov/.

[126] Measures' adoption type definitions: **Replace on Burnout (ROB)** is Replace On Burnout and implies that the technology will be adopted when the previous technology needs to be replaced.
Retrofit (RET) implies that the technology is adopted before the previous technology needs to be replaced.

stock, participation curves, and energy savings. The methodology proceeds as follows:

Equipment Stock Data

DER Planner utilizes comprehensive information on the existing equipment stock for commercial and residential sectors sourced from ComStock and ResStock datasets. This input identifies specific baseline conditions, such as the presence of equipment types (e.g., gas boilers or furnaces) within buildings. Additionally, equipment stock data enables DER Planner to estimate the number of residential dwelling units equipped with specific technologies and the floor space for commercial facilities.

Energy Change per Measure

This input calculation is derived from a combination of two key parameters: average energy use intensity (EUI) and the estimated percentage of energy savings attributed to targeted equipment upgrades. The EUI assesses energy consumption patterns within different end-uses and weather conditions (residential or commercial building types in different climate zones). In our methodology, we calibrate the EUI for each end-use category within residential dwelling units using data provided in NREL's ResStock database. In the commercial sector, the calculation of EUI is based on NREL's ComStock dataset. In this case the EUI is estimated based on square footage. To ensure alignment with the Commercial Buildings Energy Consumption Survey at the Census Division level, the calculated EUI values are appropriately scaled. Estimated percentage of energy savings: the second parameter that is key to the energy change calculations is estimated percentage of energy savings associated with specific equipment efficiency upgrades or fuel switching replacement. This percentage represents the anticipated change in energy consumption resulting from implementing efficiency measures or transitioning to equipment fueled with cleaner fuels. It is derived from technical resource manuals and industry standards and validated for each measure under consideration. By multiplying the calibrated EUI values with the estimated percentage of energy savings, our analysis generates potential changes in energy consumption across residential and commercial sectors.

Participation Rate Curves

This user-defined input includes the share of eligible stock expected to adopt each efficiency and electrification measure yearly. These curves are informed by NREL's Electrification Future Study sensitivity cases, which provide various scenarios and trends influencing the speed of electrification adoption.[127]

[127] Jadun, Paige, Colin McMillan, Daniel Steinberg, Matteo Muratori, Laura Vimmerstedt, and Trieu Mai. "Electrification Futures Study Technology Data." NREL. 2017. https://doi.org/10.7799/1414279.

Buildings and Fuel Types

Types are outlined in Table 22 and elaborated on in following tables.

Table 22. Buildings and Fuel Types.

	Residential Sector	Commercial Sector
Fuel types	• Electricity • Natural Gas • Distillate Fuel Oil	• Electricity • Natural Gas
Building Types	• Mobile home • Single Family • Multifamily	• Office • Food Service • School • Hotel • Healthcare • Retail • Warehouse

Residential Energy Efficiency

Efficient Measure	Efficient Measure Life	Baseline Measure Condition	Fuel Switch	Assumptions
Air-source heat pump	15	Existing Air-source heat pump	No	SEER 10 to SEER 14 (HSPF 6.2 to 8.2)
ASHP and ER Baseboard	15	Existing ER Furnace	No	COP of 1 to COP of 2.8
Building Shell Improvements	30	Existing Building Shell	No	ICF assumption
Deep Energy Retrofits	30	Existing Building Shell	No	ICF assumption

Efficient Measure	Efficient Measure Life	Baseline Measure Condition	Fuel Switch	Assumptions
Electric Central Heat Pump	15	Electric Central Heat Pump (older)	No	2 to 3.75 for ECHP HW
Electric Central Heat Pump	15	Electric Central Tank	No	1 to 2.35 for ECHP HW
Electric Oven and Induction Stovetop	15	Electric Stovetop	No	EnergyStar article
ENERGY STAR Appliances (Electric)	15	Electric Appliance to Elec ES Appliance	No	
Gas Boilers	25	Gas Boiler	No	80% efficient to 91% efficient
Gas Furnaces	16.5	Gas Furnace	No	80% efficient to 91% efficient
Gas Furnaces	16.5	Fuel Oil Furnace	Yes	84% furnace to 91% gas
Gas Furnaces	16.5	Propane Furnace	Yes	90% furnace to 91% gas
Gas Water Heater	15	Gas Water Heater	No	.59 EF to .685 EF for high-efficiency
Gas Water Heater	15	Existing Fuel Oil Water Heater	Yes	87% HWH to 92.5% gas
Gas Water Heater	15	Existing Propane Oil Water Heater	Yes	91% HWH to 92.5% gas
Ground-source heat pump	15	Existing Air-source heat pump	No	EER 10 to EER 18.2

Efficient Measure	Efficient Measure Life	Baseline Measure Condition	Fuel Switch	Assumptions
Hybrid Gas-Electric Heating (ASHP+Furnace)	15	Gas Furnace	No	80% efficiency w COP of 3 from fuel savings, also increased efficiency of AC from 2.5 COP
LED Lighting	15	Existing lighting	No	75% more efficient (15% of household usage goes to lighting)
Smart thermostat	15	Existing (blended prog w/ manual) thermostat	No	NY State TRM

Residential Electrification

Efficient Measure	Efficient Measure Life	Baseline Measure Condition	Fuel Switch	Assumptions
Air-source heat pump	15	Gas Furnace	Yes	80% efficiency w COP of 2.8, also increased efficiency of AC from 2.5 COP
Air-source heat pump	15	Fuel Oil Furnace	Yes	84% furnace to ASHP w/ 2.8 COP, also increased efficiency of AC from 2.5 COP
Air-source heat pump	15	Propane Furnace	Yes	90% furnace to ASHP w/ 2.8 COP, also increased efficiency of AC from 2.5 COP
Air-source heat pump	15	Fuel Oil Furnace	Yes	84% furnace to ASHP w/ 2.8 COP, also increased efficiency of AC from 2.5 COP
Air-source heat pump	15	Propane Furnace	Yes	90% furnace to ASHP w/ 2.8 COP, also increased efficiency of AC from 2.5 COP

Efficient Measure	Efficient Measure Life	Baseline Measure Condition	Fuel Switch	Assumptions
Air-source heat pump	15	Gas Boiler	Yes	80% efficiency w COP of 2.8, also increased efficiency of AC from 2.5 COP
Electric Central Heat Pump	15	Gas Central HW heater	Yes	80% gas efficiency to EF of 2
Electric Central Heat Pump	15	Fuel Oil Central HW heater	Yes	87% HWH to HP w/ EF of 2
Electric Central Heat Pump	15	Propane Central HW heater	Yes	91% HWH to HP w/ EF of 2
Electric Central Heat Pump	15	Gas Central HW heater	Yes	80% gas efficiency to EF of 2
Electric Oven and Induction Stovetop	15	Gas Oven/stovetop	Yes	32% efficiency to 85%
Electric Resistance Hot Water Boiler	15	Gas Boiler	Yes	80% gas efficiency to 100%
ENERGY STAR Dryer (Elec)	15	Gas Dryer	Yes	gas to electricity conversion
Ground-source heat pump	25	Gas Furnace	Yes	80% efficiency w COP of 4, also increased efficiency of AC from 2.5 COP

Commercial Energy Efficiency

Efficient Measure	Efficient Measure Life	Baseline Measure Condition	Fuel Switch	Assumptions
Air-source heat pump	15	Air-source heat pump	No	14 to 18 SEER
Electric Central Heat Pump	15	Electric Central Tank	No	
Electric Central Heat Pump	15	Electric Central Resistance Tank	No	
Electric Distributed Tankless	15	Electric Central Tank	No	92% efficiency to 95% efficiency
Building Shell Improvements	30	Existing Building Shell	No	ICF assumption
Deep Energy Retrofits	30	Existing Building Shell	No	ICF assumption
Gas Water Heater	15	Existing Gas Water Heater	No	80% efficiency to 92.5% efficiency
Gas Boilers	25	Gas Boiler	No	80% efficiency to 91% efficiency
Gas Furnaces	16.5	Gas Furnace	No	80% gas furnace to 91% furnace
Hybrid Gas-Electric Heating (ASHP+Furnace)	15	Gas Furnace	No	80% efficiency w COP of 3 from fuel savings for 75% of fuel use, also increased efficiency of AC from 2.5 COP
Ground-source heat pump	25	Ground-source heat pump	No	3.1 to 3.5 COP

Efficient Measure	Efficient Measure Life	Baseline Measure Condition	Fuel Switch	Assumptions
Building control systems	15	No controls	No	PNNL Study typical building
Lighting	15	Existing lighting	No	Assumes LPD of 1.1 to LPD of.61 W/sq ft
Lighting controls	8	Existing lighting controls	No	PSU Study

Commercial Electrification

Efficient Measure	Efficient Measure Life	Baseline Measure Condition	Fuel Switch	Assumptions
Electric Resistance Hot Water Boiler	25	Gas Boiler	Yes	80% gas efficiency to 100% w/ electricity
Electric Central Tank	15	Gas Central HW heater	Yes	80% gas efficiency to 100% w/ electricity
Electric Central Heat Pump	15	Gas Central HW heater	Yes	80% gas efficiency to EF of 2
Air-source heat pump	15	Gas Furnace	Yes	80% efficiency furnace w/ COP 3.5, also increased efficiency of AC from 2.5 COP
Ground-source heat pump	25	Gas Furnace	Yes	80% efficiency w COP 4, also increased efficiency of AC from 2.5 COP
Electric Central Heat Pump	15	Gas Central HW heater	Yes	80% gas efficiency to EF of 2
Air-source heat pump	15	Gas Boiler	Yes	80% efficiency boiler w/ COP 3.5, also increased efficiency of AC from 2.5 COP

Measure Intensities and Participation Curves

As an input into DER Planner, each measure has participation (or technology adoption curves) connected to them. A range of factors can impact whether new electric or efficiency technologies are adopted. This approach builds from NREL's Electrification Future Study,[128] from which many of the adoption curves are provided. It accounts for costs, supporting infrastructure, ownership and availability, health, and sustainability (including policies) and other factors that could influence technology change. Adoption curves are also provided from the implementation energy efficiency programs and informed by ICF expertise.

For ease of use, users can select prepopulated groupings of participation curves to match the types of energy change they want to model. The groupings selected for these projects are outlined below:

- HVAC Accelerated Electrification
  - Signification amount of energy efficiency, large amount of electrification prior to equipment reaching the end of its useful life
- Water Heating and Cooking Accelerated Electrification
  - Signification amount of energy efficiency, large amount of electrification prior to equipment reaching the end of its useful life
- Building Envelope Pathways Low
  - Moderate building envelope work, some deep energy retrofits

In addition to HVAC, Water Heating and Cooking Pathway selection is being chosen, there are opportunities to influence core energy efficiency work occurring in each pathway including:

- Full lighting retrofits and lighting controls
- Smart Thermostats and Building Automation Systems
- New EE appliances
- New EE HVAC equipment

Cost Methodology

To determine residential costs for measures, ICF sourced the cost of installed equipment from NREL's Residential Efficiency Measures Database[129] and HomeAdvisor. For the housing lighting retrofit, weatherization, and deep energy retrofit measures, ICF layered on industry assumptions to develop costs outlining what type of retrofit would be completed.

Commercial costs were derived from previous Pennsylvania Act 129 program costs. Total commercial costs were taken from non-residential parts of 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. Energy Efficiency and electrification costs were considered to be equivalent. Energy costs savings were derived by multiplying energy changes by AEO's utility rate projections for electricity, natural gas, and fuel oil.

[128] "Electrification Futures Study: A Technical Evaluation of the Impacts of an Electrified U.S. Energy System." NREL. n.d. https://www.nrel.gov/analysis/electrification-futures.html.

[129] "National Renewable Energy Laboratory Residential Efficiency Measures Database." NREL. https://remdb.nrel.gov/.

Strategy B5. Onsite Solar

Methods, Data, and Key Assumptions

Emissions reductions from renewable energy were projected through the forecasted adoption of rooftop solar systems in Pennsylvania. The total technical potential for rooftop solar was aggregated from NREL's Photovoltaic Technical Potential Estimates to determine the technical potential in Pennsylvania.[130] To determine an adoption rate, the most aggressive 2050 adoption scenario from NREL's Storage Futures Study (20%) was applied to the total technical potential.[131]

Existing rooftop solar capacity assumptions for Pennsylvania were sourced from PJM's 2023 Load Forecast for all utilities within Pennsylvania and then grown to meet the assumption the assumed 2050 level.

To calculate the kWh of solar output, the analysis used the capacity factor for residential solar from NREL's annual technology baseline corresponding to the geography of Pennsylvania. The incremental growth in solar output from current levels, multiplied by grid emissions factors, resulted in the potential avoided emissions from rooftop solar.

Assumptions

- Constant technical potential per building over time.
- Constant ratio of commercial to residential rooftop solar capacity.
- No incremental rooftop PV installation beyond existing in BAU case.
- Linear growth of PV installations between 2023 and 2050 in Policy Case.
- BAU emissions factors (2020 eGRID held flat).
- Prioritized Climate Action Plans (PCAP) Policy emission factors (2020 eGRID grown based on 2023 AEO Reference Case).

Data Sources

- Storage Futures Study: Distributed Solar and Storage Outlook: Methodology and Scenarios (2021), NREL.
- 2023 Load Forecast, PJM (2023).
- Solar Activity Reports, NJBPU (Dec 2023).
- Project Sunroof data explorer, (June 2019), Google.
- Annual Technology Baseline, Residential and Commercial PV (2023), NREL.
- Electric Grid Emission Factor Projections for PCAP Use, AEO 2023.
- EPA eGRID, 2020.

Cost Methodology

Costs were calculated by using estimated solar and storage deployment amounts and time periods in kW and multiplying them by the Residential and Commercial Capex, and O&M costs from NREL's Annual Technology Baseline (2023). The Advanced Policy

[130] "Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment." NREL. 2016. https://www.nrel.gov/docs/fy16osti/65298.pdf.

[131] "Storage Futures Study." NREL. n.d. https://www.nrel.gov/analysis/storage-futures.html.

case costs were used to estimate total Capex and O&M costs. Electricity cost savings were derived by multiplying energy changes by AEO's utility rate projections for electricity.

GHG Emission Factors

GHG emission reductions are included in Strategy P1.

Strategy T1. Transit and Multimodal Improvements

Methods, Data, and Key Assumptions

This measure models the resulting GHG emissions reductions if Pennsylvania implements a variety of strategies to reduce VMT. These strategies included land use changes, transit fare reductions, travel demand strategies, transit enhancements, and bicycle/pedestrian/micromobility enhancements.

This measure assessed three different mode shift and travel behavior scenarios, and the VMT reduction targets for Pennsylvania for this measure are based off the low VMT reduction scenario for that study. To extrapolate these results to account for rural areas in Pennsylvania, it was assumed that these VMT reductions are only applicable to urban areas since the impacts of VMT policy and strategies is expected to be minimal in rural areas.

According to Federal Highway Administration Highway Statistics, in 2020, on average nationally 70% of Pennsylvania VMT was associated with urban travel, while rural travel accounted for the remaining 30%. The targets of 7% passenger VMT reduction from baseline by 2030 and 9% passenger VMT reduction from baseline by 2050, with linear growth in interim years starting in 2025, were derived using this proportion of urban versus rural VMT. The same baseline VMT, vehicle population, energy consumption, and emissions by fuel type and vehicle source type from EPA MOVES4 used for measures T1 and T2 were used for measure T1.

Cost Methodology

Assumed a cost of $0.03/mile reduced for program implementation of transit and multiple modal improvements. Fuel cost savings were derived by multiplying energy changes by AEO's energy rate costs projections for fuels.

Strategy T2. Light-Duty Vehicle Electrification, T3. Zero Carbon Medium- and Heavy-Duty Vehicles

Methods, Data, and Key Assumptions

These measures model the resulting GHG emissions reduced if Pennsylvania meets the ZEV sales targets outlined by California's Advanced Clean Cars II (ACCII) rule for LDVs and Advanced Clean Fleets (ACF) rule for medium- and heavy-duty vehicles. This results in the following range of ZEV sales fractions:

	2030	2040	2050
Light-Duty Vehicles (T2)	52%	100%	100%
Medium and Heavy-Duty Vehicles (T3)	29%-74%	100%	100%
Transit Buses (T3)	100%	100%	100%

Sales curves by vehicle type within each category varied. The fractions shown in the above table represent total ZEV sales, and were further broken down by technology (e.g., BEV, FCEV, and plug-in hybrid EV [PHEV]) to sum to the total ZEV sales.

The model uses outputs from the EPA Motor Vehicle Emissions Simulator (MOVES4) to project baseline VMT, vehicle population, energy consumption, and Scope 1 emissions for on-road transportation in the state by fuel type (gasoline, diesel, ethanol (E-85), and compressed natural gas), vehicle source type, and model year. Default input values were used.

To model GHG emissions reductions in the policy scenario, for each model year, a fraction of VMT was designated as fuel type "electricity" or "hydrogen" based on the sales curve. The resulting energy consumption was found using the following equation:

$$Energy\ Consumption = VMT \times Energy\ Efficiency,$$

where energy efficiency was in units of kJ/mi for battery EVs (BEVs) and fuel cell EVs (FCEVs). BEV energy efficiencies were sourced from Alternative Fuel Life-Cycle Environmental and Economic Transportation tool (AFLEET) and FCEV energy efficiencies were sourced from the California ACF rule making and the Alternative Fuels Data Center. Scope 1 emissions were found by reducing baseline ICEV emissions by the ZEV sales fraction. Scope 2 emissions were found using the following equation:

$$Scope\ 2\ Emissions = Electricity\ Consumption \times Electricity\ Emission\ Factor$$

Electricity emissions factor projections were sourced from the result of P1.

The following additional key assumptions were made throughout the analysis:

- ZEVs exist in the vehicle fleet for the same length of time as ICEVs.
- ZEV activity/use is identical to an ICEV.
- The annual ZEV sales fraction applies to every fuel type.

Cost Methodology

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. Electric vehicle supply equipment (EVSE) capital costs and installation costs are based on a comprehensive literature review,[132] subject matter expert assumptions, and DOE AFDC data. Vehicle capital costs and maintenance and repair costs are based on data from AFLEET[133] and ICF assumptions. Fuel cost savings were derived by multiplying energy changes by AEO's energy rate costs projections for fuels.

Strategy I1. Industrial Efficiency

Methods, Data, and Key Assumptions

This measure models the resulting GHG emission reductions from thermal efficiency gains and is applied to stationary combustion emissions from direct emitters in the industrial sector.

To estimate the emissions reductions that could be achieved through the adoptions of more efficient thermal processes in industrial applications, total emissions from stationary industrial sources are quantified by industry type. Using the latest DOE

132 Pournazeri, S. 2022. "How much does electric vehicle charging infrastructure actually cost?" https://www.icf.com/insights/transportation/electric-vehicle-charging-infrastructure-costs.

133 Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool AFLEET Tool (anl.gov).

resource for industry sector decarbonization, efficiency potentials were identified for each industry type using thermal efficiency potentials when available and combined (thermal and electric) potentials otherwise. In sum, the products of the efficiency potentials and the stationary combustion emissions yielded a total thermal efficiency potential of 22.3%. Assuming this thermal efficiency potential is achieved through linear, incremental growth from 2020 to 2050, emissions reductions were calculated against the BAU case, which had no assumed efficiency gains.

Data used was from EPA Flight Facility-level GHG Emissions Data, Greenhouse Gas Reporting Program[134] and the DOE Industrial Decarbonization Roadmap.[135]

Cost Methodology

Industrial costs of efficiency were derived from previous Pennsylvania Act 129 program costs. Total costs were taken from non-residential parts of 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. Energy Efficiency and electrification costs were considered to be equivalent. Energy costs changes were derived by multiplying energy changes by AEO's utility rate projections for electricity, natural gas, and fuel oil.

Strategy I2. Gas, Fuel, and Process Decarbonization

Methods, Data, and Key Assumptions

Fuel oil to gas and electrification was modeled for industrial uses. Fuel oil industrial emissions were transitioned to natural gas for 80% of the total fuel oil use (both residual and distillate) by 2050 based and straight line of interpolations was used to project the pathway for implementation. Electrification of industrial natural gas was applied to 23% of the industrial gas use based on DOE's Industrial Decarbonization Roadmap which stated that "about 30% of the process heating demand from industrial sectors is at temperatures below 150º C, making it a prime candidate for electrification." This factor was derated to capture 75% of prime candidates (23%). Industrial gas use was transitioned to electricity using an 18% efficiency factor from ACEEE.[136]

Cost Methodology

Industrial costs of electrification efficiency were derived from previous Pennsylvania Act 129 program costs. Total costs were taken from non-residential parts of 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. Energy Efficiency and electrification costs were considered to be equivalent. Energy costs changes were derived by

134 "EPA Facility Level GHG Emissions Data." US EPA. n.d. Accessed May 22, 2024. https://ghgdata.epa.gov/ghgp/main.do.
135 "Industrial Decarbonization Roadmap." DOE. 2022. https://www.energy.gov/industrial-technologies/doe-industrial-decarbonization-roadmap.

136 "Electrifying Space Heating in Existing Commercial Buildings." ACEEE. 2020. https://www.aceee.org/sites/default/files/pdfs/b2004.pdf

multiplying energy changes by AEO's utility rate projections for electricity, natural gas, and fuel oil.

Strategy F1. Operational Efficiency

Methods, Data, and Key Assumptions

The aim of this measure is to reduce emissions from oil and gas production. It is known that roughly 50% of emissions of oil and gas production process comes from the production process rather than midstream/downstream processing. Around 10% of the wells are considered to be the highest emitters, monitoring and repairing these wells can reduce overall oil and gas production emissions by 80%[137]. This strategy models the emission reduction from repairing and/or plugging of all high emitter wells. A ramp up period of 2025-2042 was assumed.

Cost Methodology

A range of costs assumptions were made to estimate costs from implementation. It was assumed that it would cost around $2000 per month to monitor wells, $600 for one spot check, $50,000 to plug a conventional well and $300,000 to plus an unconventional well. Implementation of the spot checks was assumed to be at 2% of all wells per year, while monitoring technology was assumed on 5% of all well starting in 2025, ramping to 100% of well by 2042 (increasing by 5% each year). To estimate costs of well plugging, it was assumed that 3000 wells would be plugged from 2025-2042, with 80% of the wells as conventional and 20% unconventional.

[137] Caulton et al. 2019. "Importance of Superemitter Natural Gas Well Pads in the Marcellus Shale."
https://pubs.acs.org/action/showCitFormats?doi=10.1021/acs.est.8b06965

Strategy F2. Biomethane

Methods, Data, and Key Assumptions

Potential for Biomethane

The analysis team's evaluation for the American Gas Foundation in 2019 found various feedstock options for considering biogas and renewable natural gas (RNG), (referred to as biomethane in this study) in Pennsylvania. The analysis team assumed a high resource of biomethane from anaerobic digestion sources and a low resource of biomethane from thermal gasification applied criteria to reduce the amount of supply available by 2050 and phase in availability over the 2020 to 2050 time period. Thermal gasification feedstocks are not available in the analysis team's modeling until 2030.

Uses of Biomethane

The analysis team assumed that some feedstocks of available biomethane supply will be injected into the pipeline to decarbonize the gas supply in Pennsylvania. A portion of biomethane was first allocated for hydrogen production (specifically for blue hydrogen) and the remain was assumed to be distributed proportionally across the end-use sectors of residential and commercial buildings, industrial, and transportation based on total gas need.

Applicable Emission Factors

The analysis team assumes that RNG is carbon neutral.

Cost Methodology

The analysis includes the costs of bringing biomethane 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.

Strategy F3. Inactive and Marginal Wells

Methods, Data, and Key Assumptions

This measure aims to plug all the marginal and abandoned wells. These wells have an emission rate of one kilogram of methane gas per hour.[138] It is assumed that only 25% of the abandoned wells will be plugged by 2050 and action to plug the wells will begin in 2030 with a focus on those with the largest methane leaks. All wells were assumed to be conventional.

Cost Methodology

A range of cost assumptions were made to estimate costs from implementation. It was assumed that it would cost around $2,000 per month to monitor wells, $600 for one spot check, $50,000 to plug a conventional well. In addition to well plugging, leak monitoring and spot checks would be used for site to help prioritize locations and ensure that plugging was effective.

Strategy P1. Net Zero Grid

Methods, Data, and Key Assumptions

This strategy models the resulting GHG emissions reductions from achievement of a 100% clean grid for the state by 2050. IPM was used to model changes in the electric generating mix over time in Pennsylvania in line with clean grid goal. IPM is the same model used by EPA to analyze the projected impact of environmental policies on the electric power sector. Detailed documentation of the model is available here.

The grid emissions factor used was the output of electric power sector modeling conducted using the IPM®). IPM is a multi-regional, dynamic, and deterministic linear programming model of the North American electric power sector. The model provides forecasts of least-cost capacity expansion, electricity dispatch, and emission control strategies, while meeting energy demand, environmental, transmission, dispatch, and reliability constraints.

Key assumptions for Pennsylvania include:

- Load: 2024 PJM load forecast.
- Cost: 2023 NREL ATB capital cost and performance assumptions for new clean energy resources, with the additional inclusion of IRA tax credits for existing nuclear resources as well as new clean energy resources.
- Policy: Assumed to meet a net zero power sector for the state of Pennsylvania through a combination of clean electricity

[138] Omara, et al. 2022. "Methane emissions from US low production oil and natural gas well sites." https://www.nature.com/articles/s41467-022-29709-3

generation and a limit on carbon emissions from the power sector.

Emissions from the clean grid policy scenario were compared to a BAU scenario to determine emission reductions. The BAU scenario modeled the same assumptions except that the net zero grid goal for 2050 was not included.

Applicable Emission Factors

GHG emissions and air quality emissions for NO_x and SO_2 come from IPM.

Cost Methodology

As a cost minimizing model, IPM employs detailed accounting for costs associated with its potential decisions as it forecasts the power sector subject to constraints. Cost components reported by the model include capital costs, fuel costs, and operations and maintenance costs, all of which vary by the type of power plant made available to the model (wind, solar, battery storage, etc.). Key technology cost assumptions come from federal sources such as EPA, NREL, and EIA, and can include representation of federal incentives from the IRA, depending on the scenario.

In projecting the expansion (in terms of capacity) and dispatch (in terms of energy) of the power sector, IPM catalogs costs according to these capital and operating components and seeks to minimize the total sum of these costs at a system-level. The relevant cost components are summarized for generators located in Pennsylvania and to inform additional rate impact economic impact analyses.

Modeling two separate cases, a policy case and a BAU case, yields two sets of power sector cost streams. The difference between the policy case costs and the BAU case costs represents the costs to the power sector associated with the implementation of a statewide net zero grid policy.

Strategy L1. Agriculture Best Practices – Emission Reductions

Methods, Data, and Key Assumptions

This strategy models the resulting GHG emissions reductions from the implementation of best practices on farmlands such as feed additives, nitrification inhibitors, manure management and energy efficiency measures in agricultural management. Three emissions reduction strategies were considered and two were assessed as part of this strategy, described below.

Feed Additives

Certain feed additives, such as 3-Nitrooxypropanol (3-NOP) and nitrates, have been proven to inhibit microbial activity in the rumen, reducing digestive methane production from livestock. This strategy modeled the use of 3-NOP with the assumption that 3-NOP will complete FDA approval in 2024, based on a review of recent news. Emissions reduction potential resulting from this practice utilize guidance from USDA's "Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory" Table 4-6, which suggests a maximum theoretically achievable reduction potential of 40%. This assumption aligns with California Air Resource Board (CARB)'s estimates of 20-50% reduction potential for 3-NOP in their 2021 Draft Analysis of Progress toward Achieving the 2030 Dairy and Livestock Sector Methane Emissions Target. Baseline enteric methane emissions for the dairy sector were calculated by deriving implied emissions per head factors from the most recent inventory for the state of

Pennsylvania. These derived emission factors were multiplied by the projected livestock population through 2025. Population size was projected to decrease based on a 10-year population decrease of 12% reported by the Center for Dairy Excellence.

Because 3-NOP is not yet FDA approved, pricing for its adoption could not be accurately assessed. An estimated price was developed based on recently reported prices for the EU, where it is already available in commercial products.

Nitrification Inhibitors

Baseline annual enhanced efficiency fertilizer (EEF)-compatible nitrogen fertilizer use for PA was calculated by averaging annual farm fertilizer tonnage reported by the PDA from 2018-2022. It was assumed that 116715.7 MT of synthetic N are applied per year in PA.

Emissions from synthetic fertilizer application to managed soils were calculated following methods from USDA *Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-scale Inventory.*[139].Per this methodology it was assumed that EEFs reduce direct N_2O emissions by 33% versus application without.

Because EEFs are already available on the market, the BAU scenario assumes that EEFs are already widely used with 24% adoption for compatible products. This analysis assumes that use of EEFs will only continue to grow and reach 90% adoption by 2040.

The use of EEFs was assumed to be an additional cost of $0.08 USD/lb versus the BAU scenario based on costs reported by Minnesota extension services.

Strategy L2. Agriculture Best Practices – Carbon Sequestration

Methods, Data, and Key Assumptions

This strategy includes trainings and tools to implement agricultural best practices, such as those focused on no-till farming practices, to increase the amount of carbon sequestered by farmlands. Practices could include cover cropping, rotational grazing, silvopasture, and organic and regenerative agricultural methods, which increase soil health and capacity for long-term sequestration. The modeling of this strategy assumes that agricultural practices are implemented with the intention of reducing tillage intensity and thereby lowering GHG emissions.

This analysis assumes the total agricultural acres planted in PA will increase by approximately 2% annually based on the USDA tillage survey statistics.

The acres planted by crop was assumed to be consistent with the average percentage of acres planted by crop based on the USDA national agricultural statistics service QuickStats database.[140]

The reduction in tillage intensity as part of this strategy assumes conventional tillage acreage will transition to reduced tillage acres and reduced tillage acres will transition to no tillage acres. The reduced-till acres will reduce by approximately 30,000 acres

[139] "Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory." USDA Office of the Chief Economist. 2024. https://www.usda.gov/sites/default/files/documents/USDA-Methods-Report-2024.pdf.

[140] "USDA/NASS QuickStats Ad-Hoc Query Tool." 2024. https://quickstats.nass.usda.gov/.

annually as adoption of no-till practices increase. The adoption of no-till practices is assumed to increase by approximately 6% annually to a maximum of 98% of acres planted as a conservative estimation based on USDA's Pennsylvania Tillage Survey Statistics. All remaining acres are assumed to be conventional till.

Emission reduction by crop-tillage practice come from USDA's "Greenhouse Gas Mitigation Options and Costs for Agricultural Land and Animal Production within the United States" report for USDA's Northeast Region. Changes in yield by crop/tillage practice are based on Pennsylvania's average shares of acres planted by crop.

The yield was multiplied by the projected estimates of conventional, reduced, and no-till acres in Pennsylvania to obtain the reduced production estimates. This was multiplied by weighted revenue (dollars per short ton of production).

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 US Inventory and 2006 IPCC Guidelines for National Greenhouse Gas Inventories (consistent with the SIT).

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. MATS.

Cost Methodology

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: Estimates of fuel savings applies USDA regional estimates of fuel consumption ($/acre) for various tillage practices to the projected estimates of conventional, reduced, and no-till acres in Pennsylvania. Diesel, natural gas, liquefied petroleum gas (LPG), motor gasoline, and kerosene represents 73%, 23%, 2%, 3%, and <1% of consumption on a BTU basis, respectively, based on consumption data for the agriculture economic sector from US EPA's Inventory of US Greenhouse Gas Emissions and Sinks.

Capital cost per acre utilizes the university of Illinois' 2017 Machinery Cost Estimates applied to the projected estimates of conventional, reduced, and no-till acres in Pennsylvania.

O&M costs from plowing, planting, drilling, and spraying from USDA are weighted by crop, fertilizer usage, and tillage practice the applied to the projected estimates of conventional, reduced, and no-till acres in Pennsylvania.

Strategy L3. Land and Forest Management

Methods, Data, and Key Assumptions

Pennsylvania's 6.9 million hectares (17 million acres) of forest land are estimated to sequester about 34 million $MTCO_2e$ annually. Conservation of these existing forests will be needed to maintain current sequestration levels. Several natural strategies were evaluated for their potential to increase the carbon sequestration of forestland in Pennsylvania, extending harvest cycles and reforestation showed the highest potential.[141,142,143] 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 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. 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.

In addition to the BAU scenario, eight sequestration strategies were considered and three were assessed for their sequestration potential, described below.

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). 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. 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.

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 five-year implementation period (2022 to 2027) was assumed. Over the project period (2022 to 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 tons 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

[141] 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. https://www.sciencedirect.com/science/article/pii/S2590332220306035.

[142] 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). https://www.science.org/doi/10.1126/sciadv.aat1869

[143] 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." https://www.climatehubs.usda.gov/sites/default/files/PA_ForestCarbon_MainReport.pdf

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.

Extended Harvest Cycle

DCNR along with the US Agriculture Forest Service evaluated ten management scenarios for Pennsylvania's forests. The methods for quantifying forest sector carbon trends, mitigation potential, and substitution benefits as described in Dugan, A., et al. (2018). *Assessment of Forest Sector Carbon Stocks and Mitigation Potential for the State Forests of Pennsylvania* which presents modeling scenarios created to identify strategies that may lead to gains in atmospheric carbon sequestration and carbon storage on forest lands and 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). 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 tradeoffs 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 underrepresented 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 tradeoffs 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. This strategy reduced emissions statewide compared to the BAU scenario by an estimated 6%. This percentage was applied to the BAU scenario for each year to obtain the additional sequestration potential.

Applicable Emission Factors

Carbon sequestration factors for reclaimed forest lands are based on the study "Early Tree Growth in Reclaimed Mine Soils in Appalachia USA."[144]

Cost Methodology

Costs associated with capital expenditures of implementation were estimated using assuming costs for site preparation and annual maintenance and planting for both marginalized croplands and abandoned mined lands. Site preparation costs per hectare ranged from $900-2500, planting costs were $0-$680, and maintenance costs were $5-29, depending on the type of land and forest type. Total costs were allocated across the implementation period.

Strategy C1. Hydrogen Fuels

Methods, Data, and Key Assumptions

This measure modeled the approximate emissions reductions of switching from natural gas fuel to hydrogen fuel in the built environment, transportation, and power generation sectors. Projected hydrogen use in transportation was calculated for each model year, using outputs of EPA Motor Vehicle Emissions Simulator (MOVES4), taking the fraction of VMT outputted by the model that was designated as fuel type "electricity" or "hydrogen" based on the sales curve. The resulting energy consumption was found using the following equation:

$$Energy\ Consumption = VMT\ \times Energy\ Efficiency,$$

where energy efficiency was in units of kJ/mi for battery EVs (BEVs) and fuel cell EVs (FCEVs). FCEV energy efficiencies were sourced from the California ACF rule making and the Alternative Fuels Data Center.

For projecting hydrogen consumption for the building sector ICF used proprietary market modeling of projected hydrogen market growth in the United States. Hydrogen consumption was assumed to replace an increasing proportion of natural gas demand. These assumptions are summarized in the table below.

	2030	2040	2050
% of Natural Gas Demand Replaced by Hydrogen Consumption	1%	7%	19%

Hydrogen consumption for the power sector was generated by IPM.

Total hydrogen consumption was then divided into assumed percentages of blue, green, and pink hydrogen based upon assumed changes in the Pennsylvania energy generation mix. Based upon currently available IRS guidance on 45V tax credit application, pink hydrogen was assumed to be generated only from new steam methane reformer construction. Percentages of blue hydrogen were assumed to be higher in initial years with green and pink percentages increasing over time.

[144] 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.

Applicable Emission Factors

To model GHG emissions reductions in the policy scenario, for each model year emissions from hydrogen consumption were first calculated based on the identified consumption per hydrogen color, using the following emissions factors:

Emission factor	$MTCO_2e$ per BBTU
Blue Hydrogen Carbon Intensity	8.16
Green/Pink Hydrogen Carbon Intensity	0.00

Reductions were then determined based on subtracting the hydrogen production emissions from the emissions that would be generated from an equivalent use of natural gas, based on baseline usage in the BAU.

10% of the natural gas used in blue hydrogen production was assumed to be from biomethane.

Cost Methodology

Costs for hydrogen were developed at the cost per BBTU level and were assumed to adjust overtime as hydrogen markets change. Initial hydrogen fuel costs at plant gate were developed and were inclusive of operation and maintenance costs, capital costs for production equipment (averaged based on various production plant sizes), and input fuel (natural gas or electricity), all developed from proprietary cost modeling within ICF. Capital costs for transportation and storage equipment (pipelines and other storage equipment) were developed based upon identified hydrogen consumption needs between 2025 and 2050 and were then divided by BBTU of hydrogen produced and added to the plant gate costs per BBTU, for a final cost value.

Federal hydrogen production (45V) tax credits were assumed to be applicable for hydrogen in this strategy. Economic value generated from these tax credits was based on DOE guidance for maximum credits available per kg and an assumed conversion factor of 134,800 BTU per kg of hydrogen, resulting in the following cost credit values based upon the different types of hydrogen:

Hydrogen type	Hydrogen Production Tax Credit ($/BBTU H_2)
Blue Hydrogen	$7,418.40
Green/Pink Hydrogen	$22,255.19

Strategy C2. Carbon Capture, Utilization, and Storage

Methods, Data, and Key Assumptions

As in Strategy P1, ICF's IPM model was used to model changes in the electric generating mix over time in Pennsylvania in line with clean grid goal. Part of the compliance pathway includes carbon capture technology on coal or gas power plants, which include the federal tax credit incentive for captured carbon.

In addition to CCUS from the power sector, CCUS for industrial was modeled as an opportunity for large industrial facilities. The total emissions from every Pennsylvanian non-power plant facility that emits over 100,000 MT of carbon dioxide annually from stationary combustion was determined from EPA Flight Facility-level GHG

Emissions Data, Greenhouse Gas Reporting Program[145] data. This value served as the upper limit of feasibility for CCUS of effected industrial facilities. A total carbon dioxide capture rate of 88%[146] was assumed from a CBO report and implementation was scaled to start initially in 2030, with more rapid growth beginning in 2040 and full deployment by 2050.

Cost Methodology

Costs associated with CCUS for the power sector are included in Strategy P1.

Costs for capture, transport and storage of industrial carbon dioxide were estimated using averages from the CBO report and inflated to 2024 dollars. Federal 45Q tax credits for the capture of carbon dioxide were applied for eligible years. Cost plus tax credits were summed to determine a total cost of the strategy from industrial CCUS.

Energy Rate Methodology

Gas Rate Analysis

ICF's Gas Distribution Utility Cost Model calculates the unit cost of gas delivered to consumers by consumer category (e.g., residential, commercial, industrial), as well as the total cost of gas for all gas customers. The model solves these by incorporating information and assumptions on gas utilities' future operations. The costs of gas for consumers are broken down into three components:

- Gas pipeline and storage costs
- Utility service costs
- Gas supply costs

The model builds forecasts for each of these elements based on the historical revenue and expenses, size of the gas distribution system, and rate bases of the utilities in the state, as collected from public utility information. Other inputs into the consumer cost analysis include outputs from other analytical models such as CO_2Sight (e.g., the rest of the CAP modeling being conducted for PA). The table below summarizes the key data input and their data sources.

Table 23 Key Data Inputs and Data Sources

Key Data Input	Data Source
Historical Utility Revenue	Utility Annual Report from PA PUC Website (Annual Reports | PA PUC)
Historical Utility Operating Expense	Utility Annual Report from the PA PUC Website
Historical Depreciation Expenses	Utility Annual Report from the PA PUC Website
Historical Utility Taxes	Utility Annual Report from the PA PUC Website
Historical Utility Net Operating Income	Utility Annual Report from the PA PUC Website
Historical Utility Net Plant	Utility Annual Report from the PA PUC Website

145 "EPA Facility Level GHG Emissions Data." US EPA. n.d. Accessed May 22, 2024. https://ghgdata.epa.gov/ghgp/main.do.

146 "Carbon Capture and Storage in the United States." Congressional Budget Office. 2023. https://www.cbo.gov/publication/59832.

Historical Utility Customer Count and Gas Throughput by Sector	EIA 176 Forms
Historical Utility Cost of Capital	Utility Annual Report from the PA PUC Website
Scenario Utility Customer Count and Gas Throughput Forecasts by Sector	ICF CO_2Sight Modeling
Scenario Utility Gas Supply Portfolio – Commodity Cost and Gas Supply Sources	ICF CO_2Sight Modeling
Scenario Peak Day Demand	ICF Estimation based on throughput changes in ICF CO_2Sight Modeling
Scenario Utility Capital Investment and Operating Expenses	ICF Estimation based on High-Level Assumptions

The Gas Distribution Utility Cost Model calculates retail rates for gas utilities under traditional state utility rate of return regulation. The model first establishes the revenue requirement in each year of the study period, which is the total annual revenue required by the utilities to recover the cost of providing utility service to its customers, including a fair return on its investment. The formula below shows the key steps of calculating retail gas rate forecasts.

Revenue requirement = expenses + return on rate base

Where:

Expenses = expenditure related to providing utility service
*Return on rate base = rate of return * rate base*
Rate base = investment related to providing service
Rate of return = utilities' cost of capital

After establishing the required revenue, the model allocates a portion of the revenue requirement to each customer class, followed by the retail rate calculation for each customer class.

Retail rate of gas = revenue requirement / annual gas demand

The key outputs from the ICF Gas Distribution Utility Cost Model include:

- Annual unit cost of delivered gas forecasts.
- Consumer annual gas bill forecasts.
- Annual total cost of gas to all consumers forecasts.
- Utility annual required revenues forecasts.
- Utility annual depreciation and amortization expenses (DD&A) forecasts.
- Utility annual rate bases forecasts.

Key Uncertainties

In this project, ICF estimates the typical customer gas rates in Pennsylvania (PA) for modeling purposes and produces forecasts for PA gas utility customers by scenario (i.e., not showing results for individual PA utilities). The assumptions could be further refined in future studies investigating energy rate impacts in more detail if more accurate data is available from the utilities themselves. Some of the assumptions ICF makes are highly uncertain and should be discussed with individual utilities in future studies studying potential rate impacts in more detail to develop more accurate "company-specific" assumptions. These assumptions include:

Capital Expenditures (Capex) and Operating Expenses (OPEX) Forecasts

ICF gathered historical Capex and OPEX data from publicly available utility annual reports. Due to a lack of insights into the factors driving changes in future Capex and OPEX, ICF assumes both of these cost categories increase with inflation in nominal dollars for the "Reference Cas." ICF then uses general assumptions on how Capex and OPEX at the utilities might change based on the changes in gas throughput and customer numbers in each of the scenarios being studied for the PA Action Plan. For example, because of a need to maintain safe and reliable pipeline operations, if 50% of PA gas utility customers are electrified (distributed throughout local gas infrastructure) gas utility costs are not expected to decline by 50%. ICF has worked with other gas utilities on assumptions for how these costs might change under different scenarios, but it is an emerging area of exploration in the industry, and something that will vary by utility.

Assumptions related to Capital Expenditures (Capex) and OPEX play a pivotal role in influencing the outcomes of the model. Potential future studies looking at rate impacts in more detail should explore with utilities (or at least with additional utility data) how various decarbonization scenarios impact utility expenditures to develop more accurate gas rate forecasts. In decarbonization scenarios, utilities may reduce spending in certain areas, like system upgrades and customer-facing operations, but still need to maintain system reliability and safety. Simultaneously, they may need to increase spending in areas such as pipeline integration for connecting to RNG sources and upgrading pipelines for hydrogen blending. The forecasts for Capex and OPEX will vary from one scenario to another, and each utility is likely to adopt a unique approach.

1) **Gas supply costs:** ICF will include an assumed forecast for natural gas commodity costs, as well as costs for decarbonized gases used in each scenario (e.g., RNG). However, there is significant uncertainty on how evolving supply and demand dynamics under decarbonization scenarios might shift such costs from current forecasts.
2) **Utility asset depreciation schedule:** ICF acquired historical annual depreciation expenses and year-end net plant figures from utility annual reports. Assumptions about the average annual depreciation rate are made based on this data, and the same depreciation rate is applied throughout the study period. This assumption lacks specificity regarding utilities' asset categories and each class's depreciation schedule, and future studies may benefit from more detailed utility data.
3) **Utility cost of capital:** ICF obtained the most recent long-term debt data (2022) from utility annual reports and the state's allowed rate of return for equity. Assumptions about the cost

of capital for the hypothetical "collective" utility are based on this data, with the same cost of capital carried forward throughout the study period. However, in reality, utilities' cost of capital evolves over time based on industry dynamics, company risk profiles, and regulatory decisions.

4) Many more assumptions, such as utility upstream gas transportation costs, and revenue allocation across customer classes, could be subject to further refinement with increased data availability from utilities.

5) **Potential Regulatory Changes**: In this study, ICF did not assume any regulatory changes that may influence rate design and impacts. For example, a number of regions considering aggressive decarbonization scenarios have considered potential regulatory changes to mitigate affordability issues and/or re-allocate costs. Accelerated depreciation, transfer payments, and adjustments to fixed/variable charges are examples of potential options to address specific concerns with increased natural gas rates. While ICF has studied these with the Gas Distribution Utility Cost Model, such analysis is beyond the current scope of work.

Economic Modeling Methodology

The analysis team employed a methodology comparable to the one utilized in the 2021 CAP analysis to estimate the macroeconomic impacts. The macroeconomic modeling (e.g., changes in jobs) was conducted using a customized version of the REMI PI+ model covering the entire state. REMI is a structural economic forecasting and policy analysis model that integrates several analytic techniques including input-output, computable general equilibrium (CGE), econometric, and economic geography methodologies. REMI is a dynamic model with forecasts and simulations to include behavioral responses to wage, price, and other economic factors. It can be used for estimating national-, regional-, and state-level impacts of any policy changes. The dynamic modeling framework supports the option to forecast how changes in the economy, and adjustments to those changes, will occur on an annual basis.

REMI functions by forecasting two states of the world. The first is the state of the regional economy under some standard assumptions of employment and population changes. This first forecast is referred to as the control forecast. The second forecast, in which the model user incorporates the desired policy changes, is referred to as the alternative forecast or the simulation. The difference between the two forecasts 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, GSP, 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, GSP, and DPI 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, GSP, and DPI as outlined in Table 24.

- **Employment**: Employment comprises estimates of the number of jobs, full-time plus part-time, by place of work for all industries.
- **GSP:** The market value of goods and services produced by labor and property in Pennsylvania.
- **DPI:** 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 strategy and sector. Detailed economic modeling results can be found in GHG Reduction Strategies.

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.

- 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).
- Investments in electric energy efficiency in buildings 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 bill savings. Some negative impacts will result from the lost opportunity costs of investment and impacts to power generators from lost revenues.
- Investment in gas energy efficiency in buildings creates 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 natural gas utilities from lost revenue. Pennsylvania's large natural gas sector will experience negative economic impacts as a result of lower natural gas consumption.
- The electrification of buildings in the residential and commercial sectors is expected to have positive economic impacts in the manufacturing and construction (installation) sectors since the costs of electrification are high.
- The installation of onsite distributed solar is expected to have positive economic impacts. Some positive impacts result from growth in manufacturing and installation jobs due to an increase in 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, resulting in an increase in the disposable personal income of the residents.

Transportation sector

Investments in light-, medium-, and heavy-duty EV (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 generate 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 LCFS would result in changing revenue for the fossil fuel industry.

- Positive economic impacts from transit and multimodal improvements 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. Reducing VMT is expected to have positive impacts on average annual GSP expected at $55 million.
- 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 ICEVs), the negative economic impacts are outweighed by the positive ones.
- The macroeconomic impacts of the transition to zero carbon heavy-duty vehicles are expected to be positive. 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 positive economic impacts outweigh the negative ones.

Industrial sector

Capital expenditures for efficient equipment and electrification of the manufacturing process results in changes to electricity use (e.g., an increase for electrification but a decrease for energy-efficient equipment) and bill savings from reduced fuel usage (e.g., from reduced natural gas consumption as a result of electrification).

- The overall economic impact of implementing energy efficiency in industrial processes is positive, primarily due to bill savings.
- The economic impacts associated with industrial decarbonization vary significantly.

Fuel supply sector

These technologies require capital investment but drive energy savings through the creation of RNG. Methane reduction strategies and biomethane strategies have negative cumulative economic impacts.

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 IPM to estimate the changes in investments by generation technology including investments in capital, fixed operating and maintenance, variable operating and maintenance, and fuel demand. In addition, IPM estimates ratepayer impacts from changing generation mix, credit costs, and carbon price impacts. Each of these categories result in changing economic impacts to various industry sectors.

Investments in expanding clean and renewable resources result in positive economic impacts from manufacturing and construction (installation) jobs. In the long-term a decline in jobs associated with conventional natural gas generation is more than offset by an increase in in jobs supporting fixed operating and maintenance needs for nuclear, battery storage, natural gas with CCS, and solar and wind. Modeling shows that some jobs supporting coal fired generation with CCS shift toward jobs supporting natural gas with CCS under the strategy.

Land Use and Agriculture 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.

- The small-scale investments in feed additives for agricultural best practice implementation for emissions reduction 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.
- Agricultural best practice implementation for carbon sequestration that reduce the intensity of tillage on agricultural lands leads to negative economic impacts.
- Land and forest management practices are also expected to have net negative economic impacts.

Cross cutting technologies

Production of clean hydrogen fuel and CCUS are associated with an increase in capital expenditures and energy costs.

- The hydrogen fuels strategy has negative economic impacts.
- Implementing new CCUS technologies results in an increase in the number of jobs, but negative economic impacts by other metrics.

Table 24 Summary of Economic Modeling Results by Strategy

Strategy Name	Disposable Personal Income		Gross State Product		Job Change	
	Cumulative	Average Annual	Cumulative	Average Annual	Cumulative	Average Annual
Building Codes	$4,809	$178	$3,799	$141	29,951	1,109

Electricity Efficiency in Buildings	$15,545	$576	$22,371	$829	203,463	7,536
Gas Efficiency in Buildings	-$879	-$33	-$1,499	-$56	-805	-30
Building Electrification	-$10,213	-$378	-$17,883	-$662	-63,540	-2,353
Onsite solar and storage	$4,551	$169	$11,625	$431	76,381	2,829
VMT Reduction	-$7,480	-$277	$1,517	$56	24,487	907
LDV Electrification	$8,724	$323	$26,954	$998	196,530	7,279
Zero Carbon Medium- and Heavy-duty vehicles	$11,147	$413	$11,133	$412	85,256	3,158
Industrial Energy Efficiency	$15,506	$574	$17,759	$658	219,556	8,132
Industrial Decarbonization and Fuel Switching	-$1,275	-$47	$3,487	$129	68,454	2,535
Agricultural Best Practices- Emissions Reduction	-$1,418	-$53	-$1,019	-$38	-22,142	-820
Agricultural Best Practices- Carbon Sequestration	-$1,431	-$53	-$1,356	-$50	-19,266	-714

Agricultural Best Practices- Land and Forest Management	-$1,857	-$69	-$1,322	-$49	-29,133	-1,079
Oil and Gas Operations	-$874	-$32	-$519	-$19	-1,726	-64
RNG	-$67,477	-$2,499	-$60,821	-$2,253	-14,818	-549
Marginal and Abandoned Wells	-$873	-$32	-$442	-$16	-1,429	-53
Hydrogen Fuels	-$28,081	-$1,040	-$7,027	-$260	-53,950	-1,998
CCUS	-$1,033	-$38	-$931	-$34	1,670	62
Power Sector (IPM)	-$12,381	-$459	$1,163	$43	6,957	258

APPENDIX C Federal Funding Opportunities

Infrastructure Investment and Jobs Act

The IIJA provides $1.2 trillion for transportation and infrastructure spending, with $550 billion allocated for new investments and programs promoting sustainable, resilient, and just economic growth. Programs through which Pennsylvania will receive funds from the IIJA include:

- **National Electric Vehicle Infrastructure Formula Program (NEVI)** – $172 million to Pennsylvania over five (5) years to strategically deploy electric vehicle charging stations and to establish an interconnected network to facilitate data collections, access, and reliability.
- **Regional Clean Hydrogen Hubs** – $7 billion to establish six to ten regional clean hydrogen hubs in the United States; Pennsylvania secured funding as part of two regional clean hydrogen hub projects, the only state in the United States to do so. $750 million will go toward the Mid-Atlantic Clean Hydrogen Hub (MACH2) in Philadelphia and the surrounding area (including Delaware and New Jersey) and $925 million will support the Appalachian Hydrogen Hub (ARCH2) in West Virginia, Ohio, and southwestern Pennsylvania.
- **Energy Improvement in Rural and Remote Area**s – Grant program for $500,00 to $5 million for small

community-driven clean energy projects, a $5 million to $100 million funding opportunity for community and large-scale demonstration projects for regional specific energy challenges, and $300,00 cash prizes to assist development of partnerships and financing models for clean energy projects.

- **Grid Resilience and Innovation Partnerships Program** – up to $10.5 billion to enhance flexibility and improve the resilience of the power system against growing threats of extreme weather and climate change. Pennsylvania utilities Duquesne Light Company, PECO Energy Company, and PPL Electric Utilities Corporation received awards (totaling nearly $170 million) through the first funding opportunity of Grid Resiliency and Innovation Partnerships[147].
- **State Energy Program** - $14 million to help implement programs that include policy, planning, and education initiatives to address energy efficiency, renewable energy, energy security, and resiliency planning to help the industry, buildings, transportation, and electric power sectors with added focus on delivering support and benefits to underserved populations.
- **EE&C Block Grant** - $3 million for the state to support smaller local governments and approximately $9.8 million to local governments directly.
- **Energy Efficiency Revolving Loan Fund** - $3.3 million in new funding to capitalize or support a revolving loan fund for energy efficiency loans and audits.
- **Preventing Outrages and Enhancing the Resilience of the Electric Grid** - $8 million per year for five (5) years for the resilience of the electric grid, with additional funds available through the GRIP program.
- **Energy Auditors Training Program** – up to $2 million for energy auditor training assistance.
- **Resilient and Efficient Codes Implementation/Building Codes Assistance and Training** - $3 million received by DEP for the development of building code training programs.
- **Grants for Energy Efficiency Improvements and Renewable Energy Improvements at Public School Facilities** – William Penn School District successfully received approximately $7 million in the first round of funding from this grant.
- **Replacement of Existing School Buses with Clean and Zero Emission School Buses** – $2.5 billion for zero emission school buses, $2.5 billion for clean school buses provided through competitive grants and rebates.
- **WAP Enhancement and Innovation** – up to $2 million to improve upon existing weatherization assistance programs.

Inflation Reduction Act

The IRA is the largest ever federal investment in clean energy and climate. It is projected to fund projects that will lead to a 32-40% reduction in emissions below 2005 levels in the Unites States. $369 billion is allocated for climate and energy

[147] "Grid Resilience and Innovation Partnerships (GRIP) Program Projects." Energy.gov. Accessed October 27, 2023. https://www.energy.gov/gdo/grid-resilience-and-innovation-partnerships-grip-program-projects.

investment tax credits directly available to individual and business taxpayers as well as rebate programs. These tax credits cover:

- Clean energy; including wind and solar, energy storage, and nuclear
- Residential rooftop solar and energy efficiency
- Energy efficiency for commercial buildings and new homes
- EVs
- Sustainable aviation fuels
- Clean energy manufacturing
- Clean hydrogen and CCUS
- Clean energy workforce

The IRA also includes several grant funding opportunities that Pennsylvania can participate in to fund the strategies in this CAP.

Greenhouse Gas Reduction Fund

The Greenhouse Gas Reduction Fund (GHGRF) is a $27 billion investment to mobilize financing and private capital to fund projects aimed at reducing GHG emissions and building community resilience to climate change. This program utilizes three grant competitions to focus on direct investment, indirect investment, and LMI focused solar.

National Clean Investment Fund

The National Clean Investment Fund is a $14 billion competition for 2-3 national nonprofit clean financing institutions to partner with the private sector to provide accessible, affordable financing directly to clean energy technology projects across the country. These awardees will create financial products and will bring in additional private capital to directly fund these projects.

Clean Communities Investment Accelerator

The Clean Communities Investment Accelerator (CCIA) is a $6 billion grant competition aimed at 2-7 awardees who will in turn deliver funding and technical assistance to build the clean financing capacity of local community lenders (such as green banks, CDFIs, credit unions, and others). The CCIA focuses on financing clean energy projects in low-income and disadvantaged communities (LIDAC), growing the clean energy workforce, mobilizing capital, and expanding access to clean energy technical assistance. Projects funded using CCIA dollars must be qualified projects that reduces or avoids GHG emissions, that align with priority project category (distributed energy generation and storage, net zero emissions buildings, and zero emissions transportation), and they must be in a LIDAC area.

Solar for All

Solar for All is a $7 billion program aimed at providing funding for states, territories, Tribal governments, municipalities, and nonprofits to expand the number of LIDACs primed for residential solar investment. PEDA has received a notice of award from the EPA's Solar for All Program for $156 million that can be used to deliver solar projects to LIDAC areas, reducing energy burden and expanding distributed clean energy generation across the Commonwealth.

Climate Pollution Reduction Grants

The Climate Pollution Reduction Grants program is a $5 billion two-phase effort, beginning with a round of over $200 million in formula planning grants, which will go to DEP at the state level, and to the regional planning bodies for the Philadelphia, Pittsburgh, and Lehigh Valley metropolitan areas. The planning grants have already been awarded for the development of PCAPs, which were completed in spring of 2024. These PCAPs will become the basis for competitive grants funded under Comprehensive Climate Action Plans (CCAPs), to be awarded by September 2024.

States and regional planning bodies that developed the PCAPs, as well as other entities that are eligible for implementation grant funds, can apply for competitive CCAP funds ranging from between $2 million and $500 million in several funding tiers. CCAP funds would be used to implement specific projects or programs, which must be identified in a PCAP to be eligible. Pennsylvania has developed this 2024 CAP under existing state law, in coordination with its EPA CPRG PCAP. Any funds that are received from the CPRG implementation grant will be able to be used to further the strategies presented both in the PCAP and in this 2024 CAP.

Home Energy Efficiency and Electrification Rebate Programs (HER and HEAR)

$8.8 billion has been made available for state and territory energy offices for programs for households to achieve high-efficiency, electrified homes through rebates. Pennsylvania is expected to receive approximately $130 million from both the HER and HEAR programs to provide rebates for appliances, equipment, cover heating, electric upgrades, and insulation and air sealing measures. This funding equates to potential rebates of $2,000 to $8,000 to homeowners and up to $400,000 for multifamily buildings. These rebates can be doubled for LMI households.

Assistance for Latest and Zero Building Energy Code Adoption

$1 billion in a mix of formula and competitive grants will be provided to state and local governments to adopt the latest residential or commercial national model building energy codes, and to implement residential and commercial energy codes that exceed the net zero-energy provisions of the 2021 IECC or equivalent. $330 million of the funding is dedicated to support the implementation of a plan to achieve full compliance with latest codes while the remaining $670 million will support net zero-energy code implementation. Pennsylvania is expected to receive approximately $8.7 million for adoption of the latest national model building energy codes.

Low Emissions Electricity Program

The Low Emissions Electricity program allocates funds to the US EPA to provide technical assistance and partnerships with states to facilitate low emissions electricity generation and use. Funds will be provided to the EPA with $17 million per partnership. Many actors in Pennsylvania could potentially access these funds as partnerships can be with state and local governments, consumer-related education organizations, LIDAC, and industry actors.

State-Based Home Energy Efficiency Contractor Training Grants

This DOE program provides $200 million to states to establish and provide training and education to contractors who install home energy efficiency and electrification improvements. These funds can also be used to test and certify contractors. Pennsylvania can partner with nonprofits organizations to develop and implement these programs. $150 million from this grant will be provided through formula awards to states for the training for residential energy contractors program.

Building Resilient Infrastructure in Communities

FEMA's BRIC program provides funds to reduce the overall risk to populations and infrastructure from future hazard events. BRIC funding supports states, local communities, tribes, and territories as they undertake hazard mitigation projects to reduce the risks they face from disasters and natural hazards, including hazards that amplified by the impacts of climate change such as flooding.

FEMA has expanded the funding available for the BRIC program from $1 billion in FY 2021 to $2.3 billion in FY 2022. In FY 2021 the BRIC program set a focus to participate in Justice40 with grants focused on underserved communities to reach the Justice40 goal of 40% of overall benefits going to disadvantaged communities. Alignment with Justice40 continues in the FY2022 funding cycle.

FEMA identified 24 projects from Pennsylvania, with total funding of approximately $85 million for further review from FY 2022, applications the next step in the process for receiving funding.

APPENDIX D

Embodied Carbon

The need and urgency to limit the global warming to below 1.5°C increase of global average temperature above the preindustrial levels requires us to drastically reduce the GHG emissions caused by human activities. Buildings' significant contributions to the release of these emissions have been well documented, and national and local governments have established policies, building codes, and programs in the past decades to limit the emissions caused by the energy consumption of buildings. While these efforts persist, embodied carbon, another aspect of the GHG emissions from buildings, is receiving increased attention for emission reduction. In this section, we discuss embodied carbon and its implications.

Embodied Carbon: What Is It?

Embodied carbon is a term to reflect the GHG emissions associated with building materials and construction. Embodied carbon is, therefore, part of the Global Warming Potential (GWP) of buildings that is caused by the materiality of buildings and the practices involved in their construction, usage, transportation, and end-of-life processing. More specifically, the term captures the emissions released in the life cycle of a building to extract raw materials from their sources, transport them to factories, manufacture building materials and products, transport them to the construction site, construct and maintain the building, and potentially demolish it after a certain service life span. While the term often incorporates a 'full life cycle' or 'cradle-to-grave' connotation, it can also refer to partial life cycle. For example, the 'cradle-to-gate' embodied carbon, also known as upfront carbon, captures the GHG emissions of the building material production before materials are shipped to the construction site. As embodied carbon is a GWP concept, it is expressed in kilogram carbon dioxide equivalent (Kg CO2e).

Embodied Carbon Assessment: Techniques and Tools

Embodied carbon is assessed using the life cycle assessment (LCA) methodology governed by multiple standards including ISO 14040+A1,[148] ISO 14044+A2,[149] and EN15978.[150] The LCA methodology tracks the type and quantities of different GHG emissions released during the life cycle of a product or building and aggregates them into the equivalent carbon dioxide. The methodology involves four steps including goal and scope definition, inventory modeling, impact assessment and interpretation of results. The results of the assessment are reported in detail per life cycle stage including A1 (raw material extraction), A2 (transportation to manufacturing facility), A3 (manufacturing), A4 (transportation to site), A5 (construction), B1 (use), B2 (maintenance), B3 (repair), B4 (replacement), B5 (refurbishment), B6 (operational energy), C1 (demolition), C2 (transportation to demolition site), C3 (waste processing), C4 (disposal), D1 (reuse), D2 (recovery), D3 (recycling), and D4 (exported energy).

An important concept in estimation of embodied carbon is 'biogenic carbon'; i.e., the carbon stored in bio-based materials. Plants and forests store carbon dioxide during the photosynthesis process and, hence, could be effective means in mitigating climate change. This biogenic carbon remains stored in bio-based materials until their life ends through incineration, decay, etc. The biogenic carbon can be treated as negative (i.e., good) carbon in estimation of embodied carbon to compensate the effects of carbon emissions released into the environment by the material. The building LCA tools often allow for the estimation of embodied carbon and life cycle environmental impacts in both scenarios of including and excluding biogenic carbon. These tools also account for the carbon dioxide that is absorbed through the carbonation process of concrete in which the carbon dioxide from the atmosphere makes a chemical reaction naturally with the concrete over its life cycle.

The embodied carbon results for construction materials and building products are reported in the EPD reports in

[148] ISO14040, Environmental management: Life cycle assessment principles and framework. International Standard Organization (ISO), 2020.
[149] ISO14044, Environmental management: life cycle assessment requirements and guidelines. International Standard Organization (ISO), 2021.
[150] EN15978, Sustainability of construction works: assessment of environmental performance of buildings: calculation method. London, UK: British Standards Institution, 2012.

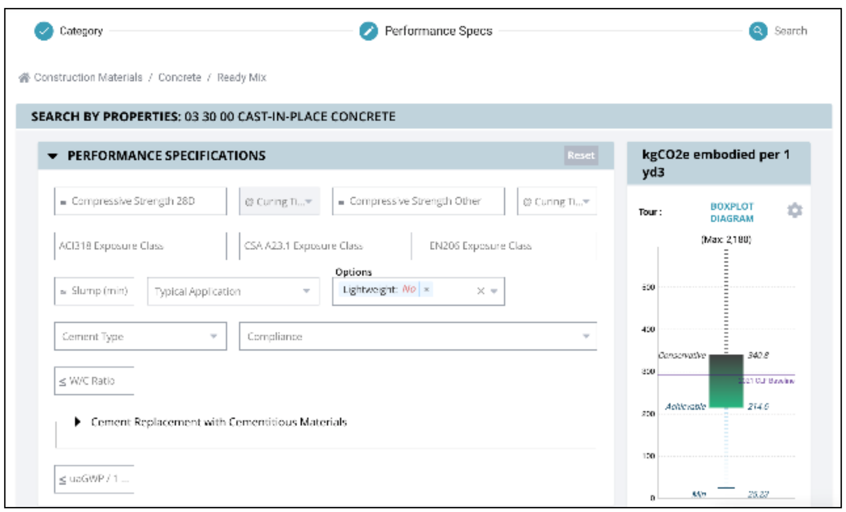
compliance with ISO 14025,[151] ISO 21930[152] and EN 15804.[153] The EPD reports are developed and verified by the third-party consultants hired by material manufacturers. These reports communicate the embodied carbon, along with other life cycle environmental impacts, for the unit of mass (e.g., one kilogram) or volume (e.g., cubic meter) of the construction materials. As the EPD-reported embodied carbon values can vary a lot, even for the same material produced by different manufacturers, Carbon Leadership Forum (CLF) has established regional and national upfront carbon benchmarks for different construction material categories including ready-mix concrete, masonry, steel, aluminum, wood and composites, insulation, cladding and roofing, openings, and finishes.[154] These baselines serve as the 'industry-average' emissions for the building products [7]. For example, CLF estimates an upfront carbon baseline value of 378 Kg CO_2e per cubic meter (m^3) for the ready-mix concrete (5000 psi) produced in the US Eastern regions, which could be compared with the national baseline value of 365 Kg CO_2e/m^3 for same concrete type [7]. A great resource to find the upfront carbon of various construction materials and compare them or construct an upfront carbon model for a building is the free-of-charge web-based Embodied Carbon in Construction Calculator (EC3) tool[155] (Figure D1).

The state-of-the-art LCA tools in the market can be classified based on factors such as modeling comprehensiveness (ability to fully model a building, ability to model the full life cycle of a building, ability to assess diverse environmental impacts), compatibility with energy simulation tools, compatibility with building information modeling (BIM) and other digital modeling tools, geographical representativeness, transparency in disclosing the methodology and inventory databases, fitness for early design stage, usability and interface, customizability of inventory data. Tools such as OneClick LCA,[156] Tally Plugin,[157] (Figure D2) to Revit, Athena Impact Estimator for Buildings[158] (Figure D3), or Cove Tool)[159] offer the capability to assess diverse environmental impacts for the entire building over complete life cycle. Examples of non-whole-building LCA tools include Kaleidoscope[160] that is used for building envelope embodied carbon modeling, Structural Carbon Tool, [161] and 2050 Embodied Carbon Optimizer Tool.[162] These tools are

[151] ISO14025, Environmental labels and declarations: Type III environmental declarations: principles and procedures. International Standard Organization (ISO), 2010.
[152] ISO21930, Sustainability in buildings and civil engineering works: Core rules for environmental product declarations of construction products and services. International Standard Organization (ISO), 2017.
[153] EN15804, Sustainability of construction works: Environmental product declarations core rules for the product category of construction products. 2019.
[154] B. Waldman, A. Hyatt, S. Carlisle, J. Palmeri, and K. Simonen, 2023 Carbon Leadership Forum North American Material Baselines. Seattle, WA: Carbon Leadership Forum (CLF), University of Washington. 2023.
[155] EC3. "Embodied Carbon in Construction Calculator (EC3) Tool." Building Transparency. 2019.
[156] "One Click LCA Tool for Embodied Carbon Assessment." OneClickLCA. 2023. https://www.oneclicklca.com/
[157] "Tally, Life Cycle Assessment App." Kieran Timberlake. 2019.
[158] "About Environmental Building Declarations." Athena Sustainable Materials Institute. 2018.
[159] "CoveTool." 2023. https://www.cove.tools/.
[160] "Kaleidoscope Embodied Carbon Design Tools." Payette. 2023. https://www.payette.com/kaleidoscope/.
[161] "Structural Carbon Tool." Institute of Structural Engineers. 2023. https://www.istructe.org/resources/guidance/the-structural-carbon-tool/.
[162] "2050 Embodied Carbon Optimizer Tool." 2050 Materials. 2023. https://app.2050-materials.com/tools/dot_selection.

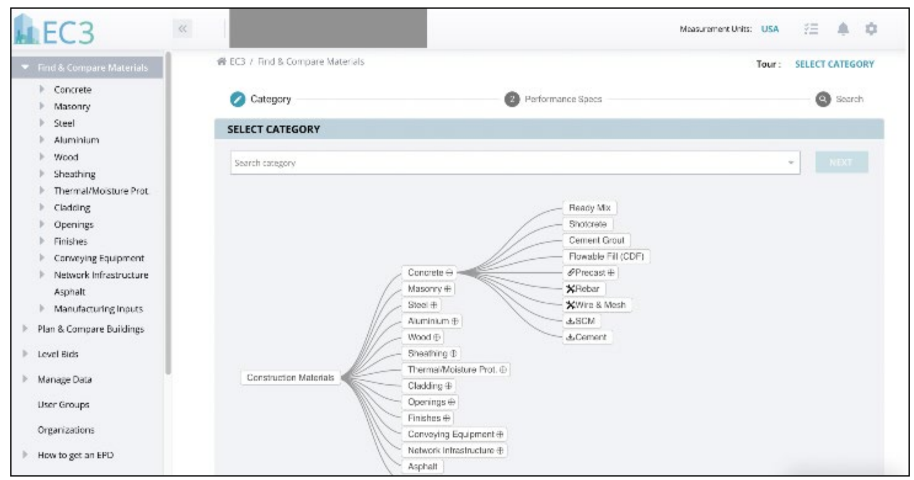
limited in their assessment of full life cycle, whole building, and diverse environmental impacts as they often assess embodied carbon only for certain building components for limited life stages. A significant gap in the current tools is in their coverage of building systems including mechanical, electrical, plumbing, and photovoltaics. There also exist general LCA tools such as Gabi[163] and SimaPro[164] that, even though are not tailored for building LCA applications, use rigorous methodologies and inventory databases that fit building LCA assessment.

Figure D1. Screenshots of EC3 tool [8] showing a) *(left)* the classes of materials to select from for embodied carbon data and b) *(far right)* the embodied carbon boxplot diagram illustrating embodied carbon statistics for a random material.



Additionally, tools such as Cove Tool allow for modeling of both embodied carbon and energy use in the Cove Tool platform.

On the other hand, tools such as One Click LCA and Tally are available as plugins to building digital modeling tools which when used along with energy simulation plugins could facilitate both LCA and energy modeling for one digital model. There are also tools such as Athena Impact Estimator for Buildings that, even though they do not present direct coupling with energy simulation, allow for manual inputting of energy use data to assess embodied carbon, operational carbon and other life cycle environmental impacts. From the BIM integration perspective, only very few tools present full integration opportunity.



[163] "Gabi: Life Cycle Assessment Tool for Experts." Sphrea. 2023. https://sphera.com/life-cycle-assessment-lca-software/.

[164] "Life Cycle Assessment for Informed Changemakers." SimaPro. 2023. https://simapro.com/.

Figure D2. Screenshots of Tally® LCA plugin to Revit [10] showing building components specification (top) and an example part of the LCA results generated by the tool (bottom).

Figure D3. Screenshots of Athena Impact Estimator for Buildings [11] showing building characteristics definition (top) and importing of a bill of materials (bottom).

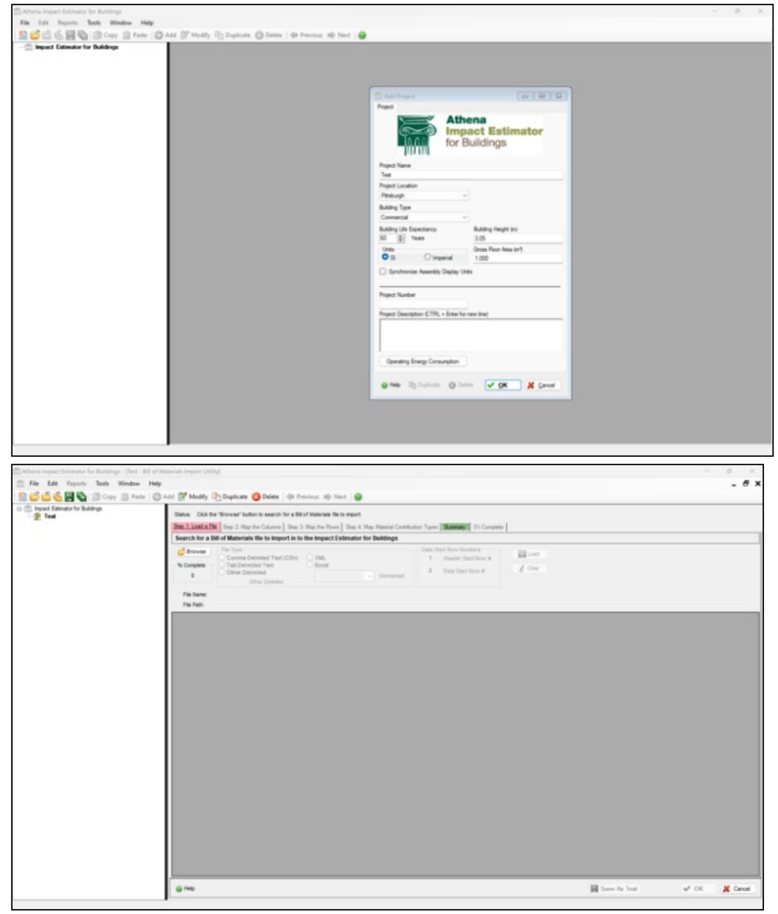
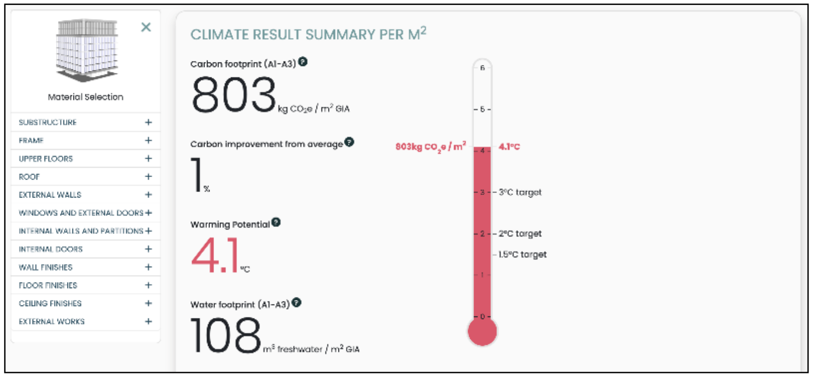
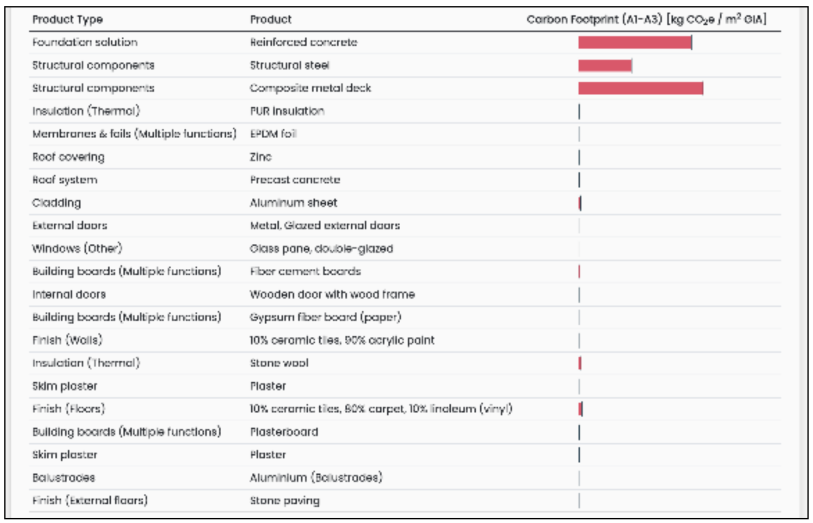


Figure D4. Screenshots of 2050 Embodied Carbon Optimizer Tool [15].





Product Type	Product	Carbon Footprint (A1-A3) [kg CO_2e / m^2 GIA]
Foundation solution	Reinforced concrete	
Structural components	Structural steel	
Structural components	Composite metal deck	
Insulation (Thermal)	PUR insulation	
Membranes & foils (Multiple functions)	EPDM foil	
Roof covering	Zinc	
Roof system	Precast concrete	
Cladding	Aluminum sheet	
External doors	Metal, Glazed external doors	
Windows (Other)	Glass pane, double-glazed	
Building boards (Multiple functions)	Fiber cement boards	
Internal doors	Wooden door with wood frame	
Building boards (Multiple functions)	Gypsum fiber board (paper)	
Finish (Walls)	10% ceramic tiles, 90% acrylic paint	
Insulation (Thermal)	Stone wool	
Skim plaster	Plaster	
Finish (Floors)	10% ceramic tiles, 80% carpet, 10% linoleum (vinyl)	
Building boards (Multiple functions)	Plasterboard	
Skim plaster	Plaster	
Balustrades	Aluminium (Balustrades)	
Finish (External floors)	Stone paving	

Embodied Carbon Regulation

The mandatory embodied carbon regulations are limited at an international level to a few countries. Norway, Sweden, Finland, and Switzerland are examples of such countries. While the building codes in the United States do not regulate embodied carbon, the Federal Sustainability Plan calls for net zero emission status in the federal sector through diverse strategies including a "Buy Clean" initiative that requires purchasing of low-embodied carbon materials, considering the social costs.[165] There are also state-level Buy Clean initiatives by states such as California, Colorado, Hawaii, Illinois, Maine, Maryland, Massachusetts, Michigan, New Jersey, New York, Oregon and Washington who have committed to prioritization of low-embodied carbon construction material procurement.[166] Additionally, the climate action plans of multiple United States cities and authorities have embodied carbon implications.[167] The New York state's 'Low-Embodied Carbon Concrete Leadership Act (LECCLA)', as an example, calls for procurement guidelines for low-embodied carbon concrete in-state projects.[168]

Embodied Carbon Mitigation

Embodied carbon mitigation must be part of the holistic approaches to decarbonization of built environments. The production of concrete, aluminum, steel, brick and glass

[165] "Federal Sustainability Plan: Catalyzing America's Clean Energy Industries and Jobs." White House. 2021. https://www.sustainability.gov/federalsustainabilityplan/.
[166] "Federal Buy Clean Initiative." Office of the Federal Chief Sustainability Officer. n.d. https://www.sustainability.gov/buyclean/.
[167] CLF Embodied Carbon Policy Toolkit." Carbon Leadership Forum (CLF). 2022. https://carbonleadershipforum.org/clf-policy-toolkit/#map.
[168] State of New York. "Senate Bill S542A." The New York State Senate. 2021. Retrieved from https://www.nysenate.gov/legislation/bills/2021/S542.

contributes 10% to global GHG emissions[169] and the main strategy for embodied carbon mitigation includes transitioning to a circular economy and closing the material loops, avoiding waste and reducing the demand for new materials[170] through extending the life span of the existing buildings and materials, renovating instead of new construction, and optimizing the building form, geometry, structure, and enclosure for lesser material consumption. Optimization of building structure is particularly important in the case of reinforced concrete and steel structures as these materials are major contributors to global GHG emissions and building embodied carbon.

Another important strategy is to replace high-embodied carbon materials with low-embodied carbon alternative materials such as mineral wool, bio-based materials, earth-based materials such as clay, and low-embodied carbon concrete that uses supplementary cementitious materials (such as fine limestone, fly ash, and slag). Finally, the sequestration of biogenic carbon that is stored in bio-based materials, timber, and engineered wood products (such as cross-laminated timber, glue-laminated timber, dowel laminated timber) offer great potential for embodied carbon mitigation. However, it is important to note that the carbon sequestration advantages of these products depend on their end-of-life treatment and are materialized in a circular economy.

Embodied Carbon of Energy-Efficient Buildings

Energy-efficient buildings have significantly grown in number and efficiency in the past decades, thanks to the increasing stringency of the mandatory requirements of building energy codes, governmental policies and programs that promote sustainable buildings, and advancements in technology and construction practices. While this has created the opportunity to decarbonize buildings through reducing the energy-related operational carbon, it is important to consider the tradeoffs between embodied carbon and operational carbon in making design decisions and material choices for buildings. The objective of architects and engineers must therefore take a holistic approach and reduce the total carbon emissions of buildings, instead of focusing on limiting either embodied or operational carbon alone.

Insulation materials are particularly important as they are important components of building enclosure that affect both energy use and embodied carbon. The higher levels of thermal insulation employed in the building enclosure of energy-efficient, ultra-energy-efficient and net zero-energy buildings translate into higher embodied carbon. With the increasing focus on embodied carbon, there have been developments to prohibit or discourage the implementation of high-embodied carbon insulation materials such as extruded polystyrenes (i.e., XPS) which are manufactured using

[169] "Tracking Clean Energy Progress 2023." International Energy Agency. 2023. https://www.iea.org/reports/tracking-clean-energy-progress-2023.

[170] "Building Materials and the Climate: Constructing a New Future." United Nations Environment Programme. Nairobi. 2023. https://www.unep.org/resources/report/building-materials-and-climate-constructing-new-future.

hydrofluorocarbon (HFC) blowing agents. Low-embodied carbon insulation materials include Graphite Polystyrene (GPS) - an HFC-free material -, mineral wool, bio-based insulation, and other materials.

Energy conservation in buildings also requires a balanced window to wall ratio (WWR) to allow for daylight availability and winter solar gain, while limiting winter heat loss and unwanted summer heat gain. WWR decisions and window choices also have embodied carbon implications, and the architects and engineers need to conduct LCA analyses to compare the environmental impacts of low vs. high WWR, triple-glazed vs. double glazed windows, or aluminum-framed vs. wood-frame windows. The literature reports that each 20% increase in WWR leads to a minimum of 10% increase in total carbon emissions of buildings over 30 years [24].[171]

A holistic approach to design of energy-efficient low-carbon buildings requires the application of modeling and simulation tools to estimate and compare the energy use, embodied carbon, and environmental impacts of the various alternatives of building massing, structure, enclosure, and systems.

[171] T. M. Echenagucia, T. Moroseos and C. Meek. "On the tradeoffs between embodied and operational carbon in building envelope design: The impact of local climates and energy grids." *Energy and Buildings,* vol. 278, no. 112589.

APPENDIX E

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 Climate Change Advisory Committee appointees and are included in this appendix. The views presented in these letters do not necessarily represent those of the DEP.

September 30, 2024

Lindsay A. Byron, P.G.
Environmental Group Manager
Energy Programs Office
Department of Environmental Protection
Rachel Carson State Office Building
400 Market Street
Harrisburg, PA 17101

Re: 2024 Climate Action Plan

Dear Ms. Byron,

I am writing in my individual capacity as an appointed member and recently elected Chair of the Climate Change Advisory Committee to the Department of Environmental Protection to express my support for the Department's 2024 Climate Action Plan. I believe the 2024 Plan provides an ambitious yet achievable roadmap for the Commonwealth to implement meaningful, cross-sector climate mitigation strategies that will help to alleviate the negative impacts of climate change on individuals, families, and communities.

I am particularly encouraged by the Department's emphasis on addressing the unique needs of low income and environmental justice (EJ) communities in each section of the 2024 Plan. Low income and EJ communities are disproportionately impacted by our changing climate and the acute health and economic harms associated with extreme weather. Vestiges of redlining and other disparate socio-economic factors drive broad disparities in energy, water, and housing burdens, which undermine resiliency across low income and EJ communities in all corners of the Commonwealth. Without careful planning and thoughtful policy, low income and EJ communities are also disproportionately burdened by the financial costs of climate mitigation. Indeed, climate mitigation requires substantial investment in all facets of our built and natural environment, and comes at a cost that low income and EJ communities simply cannot afford to bear.

The 2024 Plan includes explicit equity analysis identifying ways each climate mitigation strategy may impact vulnerable populations, together with strategies to reduce or eliminate potential disparities or unintended consequences. Inclusion of this express equity analysis in each section of the 2024 Plan will help to prevent unintended consequences that could add to the burdens already shouldered by low income and EJ communities. Ultimately, however, it will be incumbent on those implementing the Plan to integrate these explicit equity considerations directly into the resulting policies and programs. As such, I urge the Department to ensure that equity remains a focal point through implementation. Specifically, I recommend that the Department identify metrics for tracking and assessing progress on equity to help inform its next climate action plan.

I am also encouraged by the Department's inclusion of an energy rate analysis within the 2024 Plan, which attempts to identify impacts of climate strategies on energy costs. It is critical to understand the impact that climate mitigation strategies will have on energy costs, and I support inclusion of an energy rate analysis in the Department's Climate Action Plan. Nevertheless, and notwithstanding my support for inclusion of an energy cost analysis, I note that the energy cost analysis included in the 2024 Plan lacks the complexity necessary to fully assess energy cost impacts across sectors, geographic regions, and socio-economic divisions. I urge the Department

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to dive deeper into this analysis in future climate action plans. Specifically, future energy rate analysis should include a distributional energy burden analysis necessary to identify the impact of various policies on households with varied economic means. This will help to better identify equitable policy solutions necessary to advance climate mitigation strategies while minimizing unintended consequences to vulnerable populations.

I also want to note my strong support for the Department's emphasis on improved inter-agency and cross-sector collaboration throughout the 2024 Plan, including the explicit identification of partners and stakeholders necessary to drive implementation of each strategy. Climate work is intersectional work and calls for intersectional solutions. The Plan's focus on building strong inter-agency processes and increasing broad stakeholder collaboration will help to break down silos that have for too long served to slow progress in advancing equitable climate policies.

It is important to note that this letter is not intended to identify my personal or professional perspective on each policy or mitigation strategy identified in the 2024 Plan. There are dozens of recommendations throughout the Plan, many of which I support – and a few which I would caution against. That said, I wish to express my overwhelming support for the policy solutions identified in the 2024 Plan that will improve the efficiency and resiliency of our housing stock – both for single and multifamily homes – with a focus on affordable housing for low income communities. Safe, resilient, and efficient housing is the keystone building block of a thriving community and an essential ingredient for equitable climate mitigation. Pennsylvania's housing stock is among the oldest in the country, and disparities in access to safe, resilient, and efficient homes are exacerbating deep inequities in health outcomes and economic security of low income and EJ communities across the Commonwealth. As climate concerns grow, these disparities are becoming even more pronounced. I note that Governor Shapiro recently announced a new initiative to develop a comprehensive housing plan for the Commonwealth. As that planning process gets underway, I strongly encourage the Department to lean into the inter-agency strategies identified in the 2024 Plan, ensuring climate mitigation policies identified in the 2024 Climate Action Plan are appropriately integrated into the Commonwealth's forthcoming comprehensive housing plan.

I applaud the Department for its diligence and hard work in developing the 2024 Plan. It is a comprehensive body of work, and fairly represents a broad range of perspectives and ideas that – if enacted – will help strengthen communities and improve our resiliency to climate impacts. Finalization of the 2024 Plan is a true accomplishment for which the Department should be congratulated. That said, the hardest work lies ahead to move this Plan forward from concept to implementation. In my capacity as Chair of the Climate Change Advisory Committee, and through my professional role as Executive Director of the Pennsylvania Utility Law Project, I look forward to working with the Department to breathe life into this Plan – ensuring the words on the page are transformed into action in service of our communities.

Respectfully,

Elizabeth R. Marx, Esq.
emarx@pautilitylawproject.org
Chair, Climate Change Advisory Committee to the Department of Environmental Protection

2

September 30, 2024

Lindsay Byron
Energy Programs Office
Department of Environmental Protection
400 Market Street
Harrisburg, PA 17101

Re: CCAC 2024 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 fifth 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 the advisors and for having the CCAC engaged in the development and review of the CAP. It was a pleasure collaborating with DEP and the ICF team. The Advisory Committee's goal is to help the Governor's office and State Legislators develop policy for the climate, environment, health, and vitality of Pennsylvania. To that end, this edition of the CAP provides some Legislative Recommendations to aid in the implementation of identified strategies.

The targets of 2019 Executive Order are to reduce GHG by 26% by 2025, and 80% by 2050 (from 2005 levels). There are 22 primary GHG reduction strategy categories discussed and modeled in the 2024 CAP to demonstrate how the Commonwealth can potentially achieve these significant changes. The incentives and programs of the IRA and IIJA provide an unprecedented opportunity to invest in these policies in the next few years. The report provides advice and many examples on how policy can help maintain prosperity, growth, and provide a sound approach to climate change.

Flooding in Pennsylvania is most impactful. Therefore, updating the Pennsylvania Municipal Planning Code has the potential for great effect in land planning and has the added benefits of potentially addressing the housing crisis as well.

Of course, 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. We need real commitment to net-zero buildings, heat-pump technology, and community solar to achieve the targets.

In the Transportation sector we must continuously support the development of alternative fuel vehicle systems, EVs and H2.

| **Steve Krug**
| AIA, PE LEEDap, AEE Fellow
| Principal, Architect

Pennsylvania is a leading energy producer, and I am appreciative of the benefits of high-efficiency natural gas technology, but I'm concerned about being overcommitted in any one area. To achieve the goals, set out in the CAP and Executive Order 2019-01, the Commonwealth will have to address the challenges of the Industrial and Power sectors because they use a large percentage of fossil fuels.

The 2024 Climate Action Plan (CAP) maps out an approach to reducing the use of fossil fuels over the next 26 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 continue to 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 such as H2 for CHP opportunities, just to name a few of the opportunities for businesses and industry to adapt. PRESS (raising the AEPS) and PACER (Climate Emission Reduction) programs can help vary the mixture of energy sources and reduce greenhouse gases. Maintaining our nuclear fleet of power plants is especially important as the capacity of the electric power grid will continue to grow.

I am looking forward to future discussions about low embodied carbon procurement policies and show businesses how to shift our use of energy to innovative technologies as we lead the way, adapt to a changing climate, and reap the economic benefits of a competitive Pennsylvania. Strong building renovation incentives will help lead the charge by reusing existing buildings.

Finally, I want to thank AIA Pennsylvania and Krug Architects for their support of my involvement in the CCAC. The CCAC has made an impact over the years, as we have seen several legislative and executive actions. We still have a long way to go.

Sincerely,

A. Stevens Krug, AIA, LEED™*ap*, PE, AEE Fellow
Principal
Krug Architects

Lindsay Byron, P.G.
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Department of Environmental Protection
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September 30, 2024

2024 Pennsylvania Climate Action Plan Comments

Dear Ms. Byron and the Entire PA Department of Environmental Protection,

Thank you for the opportunity to provide comment to the 2024 Pennsylvania Climate Action Plan. I would like to thank PA State Senator Jay Costa (D - Forest Hills) for my appointment to this important Committee and to acknowledge Stevens Krug for his wise and steady leadership as Chair of the Climate Change Advisory Committee (CCAC), my 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 nine years, and to the CCAC for their trust in elevating me to the role of Vice Chair for this Plan, and for which I have now termed out. I would also must thank my firm **evolveEA**, where I serve as Cofounder and Managing Principal, for their support of my service.

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The Pennsylvania Climate Action Plan carries weight as an objective evaluation and as an instrument. The 2024 Climate Action Plan includes mitigation and adaptability measures to address climactic forces already in progress, addresses the human health impacts of climate change, and now has an implementation plan for engagement in all parts of the Commonwealth. 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. These take into account the companion annual Impact Assessment, our economic and demographic forces, and our role as the nation's largest exporter of electricity. This is a complex puzzle, so where Pennsylvania goes, the nation can surely follow. This Plan provides leadership, but is not intended to be in a vacuum. It has been very encouraging to see Pennsylvania's counties and municipalities create, adopt and execute their own local climate action plans (LCAPs). Indeed the top-down and bottom-up engagement has the potential for synergies and innovation.

We are pleased to share the results of this collaborative process leading to the 2024 Pennsylvania Climate Action Plan and I would like to use my personal perspective to provide the following comments for constructive consideration.

We Need Fossil Fuels. In my work leading a green building and sustainability consulting and design firm, I work with the two sides of the fulcrum. On one hand, the climate is warming and we must globally and urgently move away from the combustion of fossil fuels; on the other hand the necessary technologies and delivery systems do not yet exist in order to comfortably address an ever-increasingly energy-hungry world. Energy use is essential to quality of life. We know what to do to wean ourselves from the burning of fossil fuels and this Plan shows the steps necessary for us. We need to place ourselves in a transition mindset that allows energy efficiency, energy recovery, electrification and renewable energy to be prioritized with steady movement towards our emissions goals. We must take long term perspectives in making our decisions and while it may be tough to say that we need fossil fuels to make this transition, we really do need fossil fuels in order to make this transition.

Targeted Federal Laws are Catalyzing Meaningful Mitigation. The Democrat-led Inflation Reduction Act and Bipartisan Infrastructure Law are addressing considerable infrastructure and clean energy modernization and innovation. These laws have each committed $1 Trillion in reasonable and far-sighed funding for a wish list of carbon reducing strategies. These are on a national scale and offer most funding on a matching time-bound basis. Better yet, the spend is over a decade, which provides a signal to industry that there will be a predictable market for innovations. In the case of Pennsylvania, the plugging of fugitive wells, the acceleration of photovoltaic systems, the stimulation of energy efficient technologies and the funding for public engagement are just a few examples of this progressive and farsighted legislation. These laws and their largesse are not intended to be permanent, only to serve as catalysts to foster the clean energy industries of the next century.

Health Impacts of Generation. Hydraulic Fracturing has become a permanent part of our landscape and energy projections, so there must be acceptable and accurate study of the human and environmental impact of extraction. Akin to a century ago when asbestos was required by law for building construction while long term health impacts were not known for decades, I am alarmed at the lack of study of the health impacts of hydraulic fracturing. What good are cheap energy, energy jobs and energy independence if health risks are potentially worse than imagined. Early preliminary studies in the Pittsburgh region show potentially higher health risks for those living near pads and higher incidents of asthma for children. It is also documented that water runoff is impacted. While fracking has been a boon to our economy and our energy independence, the health impacts cannot be waved off as "junk science," as one Committee member told me. Valid and accepted health research must be prioritized.

Impacts of Climate Inaction. I would like to commend the emphasis on Environmental Justice in this Plan, as poorer, denser areas will suffer disproportionate health impacts, particularly among the elderly, less robust and those without means. The 2024 Impact Assessment predicts an astonishing 6.7F degree increase in Pennsylvania's temperatures by 2050, just over two decades from now. With the fuss over the UN's 1.5 degree Celsius line in the sand, the projection for our communities nearly triples this. It would be nice to believe that business interests will look out for us, yet this is belied by the inherent need for corporations to show continuous profits, and for many corporations the denial of climate change of any sort is good business. This laissez-faire strategy is mapped in the Climate Action Plan as the Business As

Usual (BAU) scenario. The BAU does not show significant carbon reductions, much less necessary ones. Disinformation and working against evident science impairs our ability to build consensus and make necessary change, while simple stalling is its own type of harmful behavior.

We Need to Benchmark Against Other States. It would be helpful to see how our CAP compares to those of other states nationally. Future plans would benefit from a survey of other states' emissions goals and how they are actually performing. While Pennsylvania is unique as an energy juggernaut with extraction as a significant part of our folklore, a large energy exporter able to meaningfully curb emissions can be a national and even global model. This can provide an opportunity for us to be a triple bottom line leader - economically, equitably and environmentally.

Legislative Recommendations. The reference to state legislation related to climate action is an exciting new aspect of this Climate Action Plan. While the intention is to acknowledge proposed legislation that can assist the Commonwealth in meeting our climate action goals, this approach could be detrimental if too specific. Bills have supporters and opposition based upon more complex factors than simple decarbonization. It would be helpful for any legislative recommendations to simply highlight the strategies, such as establishing a price on carbon, for example.

We Need a Price on Carbon. We can't value what we can't measure. Carbon has a social cost that we all indirectly pay, for example with climate disasters and health impacts, but that we do not pay in the cost of fossil fuel derived energy. While Pennsylvania has technically adopted the Regional Greenhouse Gas Initiative (RGGI), its implementation has been fought and delayed. Governor Shapiro has unveiled a renewed executive effort of PACER and PRESS, which would create an emissions trading market within the Commonwealth, as opposed to RGGI's 10-state market. The benefit of either of these plans is that the generated excess pollution will be addressed with market-based disincentives. These plans are not a tax, but are a legitimate fee, the proceeds of which would assist with coalfield justice, workplace transitions education and innovation.

We can't look at fees as "taxes," but rather as "investments." Investment is more than simply paying money to expect a larger return in the future. Investment is a mindset, the idea that appropriate and disciplined decisions now will be leveraged for quantifiable and qualifiable benefits in the future. These returns may well be for a time beyond our personal benefit. The Climate Action Plan shows how we can get to the 80% reduction by 2050 and shows the ROI of the strategies proposed. We know what to do. What we need is a desire to perform the right actions.

Our economic system is driven by expediency and speed to market. **There is urgency in the application of the strategies of this Plan**. As mentioned above, Pennsylvania temperatures will rise on average over six 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, infrastructure fatigue, air conditioning demand 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,

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Comments Regarding the Department of Environmental Protection's

Climate Action Plan Update 2024

Terry R. Bossert

Introduction:

I appreciate the opportunity to comment on the 2024 Climate Action Plan (CAP). The following comments are mine alone and should not be attributed to any client or employer present or past.

First a bit of history to provide prospective. As DEP Chief Counsel I thought that climate change issues were of such importance that Don Brown was authorized to address climate issues from his office in the Office of Chief Counsel, rather than carry out the usual duties of an attorney in that office. I continue to believe that climate change is an issue that needs to be addressed. However, it must be addressed in a balanced and practicable manner. Unfortunately, the climate change movement has become the business development department for the wind and solar industries and for consultants who write plans and studies. While the 2024 CAP includes several worthwhile strategies, the biases and inequity in approach taint the entire effort.

Inequities and Biases:

1. Air Quality Health Impacts. The "final" version of the CAP that was initially provided for review contained language that seemed to inaccurately imply that natural gas combustion produced significant SO_2 emissions. That language has been clarified in the current "final" version of the CAP. I appreciate the clarification. However, the CAP still asserts that air quality will be improved due to less fossil fuel combustion "as well as a reduction in upstream emissions (associated with fuel extraction and transport)." Upstream emissions are not addressed elsewhere in the CAP and limiting the scope to extraction and transport does not cure the inequity but only magnifies it. If you only consider one type of upstream emission you are stacking the deck. Isn't silica sand a fuel for solar panels? Why are the emissions from that extraction not considered. If oil and gas upstream emissions are considered when evaluating air quality impacts, then upstream emissions related to the other strategies should also be considered.

2. F3 Plug Inactive and Marginal Wells. Incredibly this "Opportunity" suggests that the owners of these wells can be motivated to plug them to avoid the costs of onerous regulations, citing to EPA's Methane Rule. It is even suggested that "Additional incentives could be phased in" if the previous regulations were not enough to drive the owners to plug the wells. The CAP is replete with references to grants, subsidies and other funding for favored activities but no such recommendation is made here. As I have commented previously, many of these marginal wells provide "farm taps" – free gas to the landowner/lessor – as well as an income to the well operator. No

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consideration is given to the loss of income to the well operator, the loss of supply to the lessor or the value to the gas left behind. No compensation is offered. All to get a reduction of less than 4.5 MMTCO2e by 2050. This strategy is cold-hearted and probably a regulatory taking requiring just compensation to the lessor and lessee.

3. C2. Carbon Capture, Utilization, and Storage. The CAP emphasizes that CCUS technology does not capture all air pollutants. Why is that highlighted here? Many of the strategies do not result in zero emissions of either CO2 or other pollutants, but that is not emphasized in the discussion of those strategies. Roof top solar while an appropriate strategy will not eliminate all emission from electricity production. While "CCUS technology" will not capture all pollutants the subject facility will have a permit requiring other technology to capture NOX, PM 2.5 and the like and limit emission to levels deemed by EPA to be protective of human health. The constant reference to other "harmful emissions" as though they are uncontrolled is another illustration of bias toward any technology other that wind and solar.

Transparency:

1. T2. And T3. These two strategies are projected to produce very significant GHG emissions. To reach these targets Pennsylvania would need to meet the ZEV sales targets outlined in California's Clean Cars and Clean Fleets rules – in other words adopt the California program. However, that fact is not apparent in reading the main text of the report. One needs to explore Appendix B to get that information. Something this potentially impactful should be in the main text in order to present a clearer picture.

2. P1. Net Zero Grid. This strategy predicts significant GHG reductions. However, the metrics for "Opportunities" B2, B5, and P2 are all subsumed into P1. Thus, it is not possible to determine the cost/benefit ratio for these individual strategies. Why is the cost and GHG reduction anticipated from electric efficiency and onsite solar hidden in the P1 analysis? The reader should be able to determine whether these strategies produce reductions worth the cost. Perhaps they do, but that cannot be determined.

   As the CAP acknowledges, strategy P2, addressing grid reliability and enhancement, does not itself result in GHG reductions, but is essential to the success of other strategies. However, once again the reader cannot determine the cost of these necessary enhancements. Frankly, it is difficult to credit the relatively low cost per ton assigned to strategy P1 when one considers the cost of new transmission lines and related infrastructure.

Implementable:

The CAP sets out a wish list of "Opportunities" but fails to perform any but the most cursory evaluation of implementability. The CAP is devoid of any candid discussion of the obstacles that may face each strategy. As such the CAP is not an "action" plan. It cannot be a reasonable guide to action unless it accurately addresses the obstacle that may be faced. A particular strategy may produce a huge reduction in GHG but face such implementation obstacles to make it unattainable. Policymakers should know about these limitations when making decisions. For example, enhancing the transmission grid may be a key requirement in order to attain a net zero grid. However, opposition to new transmission lines has frustrated many projects in the past. Why should that be any different for "green" transmission lines? Shouldn't decision-makers know about and consider these challenges. Likewise, there has been growing local opposition to new wind and solar projects. Shouldn't those be discussed and recognized? In short, the CAP advances numerous strategies but fails to explain which can be implemented.

Conclusion:

The CAP contains several worthy strategies, but their worth is overshadowed by the way the CAP is manipulated to suit an agenda. This CAP checks the box to produce a plan on schedule. Unfortunately, it is incomplete and biased. It does not give policymakers a clear picture of what it attainable, merely providing shallow talking points for political posturing.

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2024 Pennsylvania Climate Action Plan Comments
Flora Cardoni
September 30, 2024

I would first like to thank the Pennsylvania Department of Environmental Protection (DEP) for my inclusion in the Climate Change Advisory Committee and opportunity to comment on this plan. I also appreciate their commitment to tackling climate change and the immense time and effort that goes into this essential planning.

Given what we know about climate change and the impacts that Pennsylvanians are seeing every day — record-setting rains, flooding, extreme temperatures and more — and the fact that Pennsylvania emits the fourth highest amount of climate pollution in the country, it's critically important that we reduce greenhouse gas emissions in the Commonwealth as swiftly as possible. I therefore appreciate that the targets laid out at the beginning of the plan are in line with what the scientific community says must be achieved to avoid the worst impacts of climate change: cut greenhouse gas emissions in half by 2030 and achieve net zero emissions no later than 2050. This is critical to ensuring that future generations of Pennsylvanians have a livable planet to call home.

Unfortunately, it appears that the proposed plan will not accomplish the very goals it says it must achieve. The report acknowledges that all of the strategies in the 2024 plan are only projected to cut greenhouse gas emissions 80% by 2050, and Page 7 of the plan states that "more reductions will be needed to meet both short (2030) and long (2050) term climate targets."

This is even more concerning given that the proposed plan does not consider the growing energy demands related to data centers and AI, which will make reducing our energy use via energy efficiency and transitioning to clean, renewable energy even more difficult.

For this reason, it is critical that Pennsylvania's decision makers think of this plan as the *floor*, rather than the *ceiling*, of needed climate policies. I hope that the Commonwealth will be even more ambitious than what is suggested in the proposed plan in terms of moving away from dirty dangerous fossil fuels, to clean renewable energy like wind and solar. I also urge them to move swiftly to implement these policies, given the little time we have left to meet the targeted 2030 emissions reduction goals.

Beyond the failure of the plan to go far enough to reduce emissions, I have specific concerns with some of the emissions reductions proposals included in the plan.

Of particular concern is the proposed inclusion of blue hydrogen, which many experts agree will only increase climate emissions and continue our reliance on dirty fossil fuels. This will make it harder to achieve the milestones set out by the scientific community to address climate change. The development of blue hydrogen will spur the buildout of more fossil fuel pipelines and natural gas infrastructure, causing more methane pollution and threatening our health and climate.

Blue hydrogen modeling also relies on carbon capture and storage, which is still an untested technology and will be extremely expensive for ratepayers. So climate emissions from blue hydrogen will likely be greater than the plan suggests. Ultimately, we should only use hydrogen for the hardest to decarbonize sectors, focusing on electrification and clean energy for most others, and we should only be using green hydrogen, from truly clean, renewable energy for those sectors.

I am also concerned with the proposed buildout of biomethane infrastructure. Any increased use of gas will only create more of a market for natural gas, leading to more buildout of traditional fossil fuel infrastructure. We should be moving to a future that is powered by clean, renewable energy, not deepening our reliance on gas. Additionally, this energy source will only add a miniscule amount to the overall energy mix, and much of it is already captured today. To act otherwise is misleading and will likely only distract from bringing truly systemwide solutions online. If biomethane use is increased, it should include the commitment to only use this energy for the very hard to electrify sectors, instead of being thrown into the general energy mix where true renewables can do the job. Furthermore, instead of focusing our efforts on building out a biogas system, we should be moving towards a zero waste future and reducing food waste by reducing overproduction, implementing composting etc., not creating a market for more food waste. And at the same time, we should focus on energy efficiency, electrification, and actually clean, renewable energy.

Similarly, I do not think biomass is an appropriate climate solution. Not only are carbon emissions produced when it is burned, but biomass energy production can cause air pollution, threaten public health, and result in ecosystem damage.

I am also wary of low carbon fuel standards being included in the plan. Alternative fuels mean that the cars still burn fuel. This means that the communities these cars are driving through are still suffering from air pollution. As such, I would much rather see incentives for electrifying transportation, expanding electric vehicle charging, and producing truly clean, renewable electricity for that charging. That is best for our air, health, and climate.

Finally, given what we need to do to tackle climate change, there seems to be a missed opportunity in the plan to make an explicit policy recommendation that would get us closer to a net zero grid and 100% renewable energy future.

In conclusion, in order to stop the worst impacts of climate change, policy makers should be doing everything in their power to improve energy efficiency and conservation, electrify everything that is possible to electrify, and transition to 100% clean, renewable energy as swiftly as possible. These are usually the cheapest, fastest solutions available, and they are time-tested and successful. Policy makers should also avoid any policies that would further entrench us into fossil fuels, putting our health and safety at risk. I look forward to continuing to work together to build a greener and cleaner world where all Pennsylvanians have a livable climate to call home.

Flora Cardoni
Philadelphia, PA 19143

Comments on 2024 Pennsylvania Climate Action Plan Update

As a member of the Climate Change Advisory Committee (CCAC), I have appreciated the opportunity to participate in the committee meetings and provide feedback to the Pennsylvania Department of Environmental Protection (Department) on the 2024 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 sixth iteration of the CAP under the Pennsylvania Climate Change Act (Act 270 of 2008) 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 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.

My comments will focus primarily on the strategies to reduce greenhouse gas (GHG) emissions in the Power Generation Sector. Specifically, I am concerned with the continued overreliance on emissions reductions from this sector, the failure to address electricity reliability impacts of the proposed strategies, the lack of recognition of the GHG emissions risks posed by abandoned mine lands (AML) and coal refuse piles, and the risks posed to the coal refuse reclamation-to-energy (RTE) industry by the proposed legislative recommendations.

Overreliance on energy generation sector

This CAP continues to place the largest share of the GHG reductions either directly or indirectly on the existing electric generation fleet. This is despite the fact that Pennsylvania electric generating units (EGUs) have already produced the largest reduction to the state's GHG footprint. This is a critical point on what Pennsylvania has already accomplished to date in terms of reducing 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 3 plants, all of which are scheduled to retire or and switch from coal to natural gas by the end of the decade. As noted in the CAP, the bulk of the carbon dioxide (CO_2) reductions in Pennsylvania since 2005 have come primarily from coal-fired power plants being shut down.

Prior to 2014, there were 15 coal refuse fired plants in PA – 6 bituminous and 9 anthracite. Of these, five facilities have been permanently retired. Several others have operated at limited capacity 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 and the continued environmental risks associated with those piles, including acid mine drainage (AMD), spontaneous combustion and active pile fires.

Failure to address electricity reliability concerns

The CAP calls for creating a carbon free electric grid by 2050 while at the same time increasing electrification of end-use sectors, namely transportation and buildings, which will lead to increased demand for electricity. In recent years, the regional grid operator PJM Interconnection has repeatedly raised concerns that its energy demand is set to outpace its energy production, especially as over a fifth of its existing power generators, largely coal and natural gas plants, will retire by 2030. Some states have already had issues meeting demand. For example, PJM found that shuttering a coal power plant in Maryland would negatively affect grid reliability and refused to approve its closure. The plant, Brandon Shores, has been forced to stay open and could continue operating until 2028 under an expensive operating agreement while $800 million in transmission upgrades are completed.

Maintaining an adequate level of generation resources, with the right operational and physical characteristics, is essential for PJM's ability to serve electrical demand through the energy transition. PJM's research highlights several trends that present increasing reliability risks due to a potential timing mismatch between resource retirements, load growth, and the pace of new generation entry. While the growth of electricity demand is likely to continue to increase from electrification coupled with the proliferation of data centers in the region, thermal generators are retiring at a rapid pace due largely to economic pressure from government policies. Retirements are at risk of outpacing the construction of new resources, due to a combination of industry forces, including siting and supply chain, while PJM's interconnection queue is composed primarily of intermittent and limited-duration resources. The PJM market monitor noted that renewables can replace a significant amount of the energy output but cannot replace the capacity. Given the operating characteristics of these resources, multiple megawatts of these resources are required to replace 1 MW of thermal generation.

For the first time in recent history, PJM could face decreasing reserve margins should these trends continue. The amount of generation retirements appears to be more certain than the timely arrival of replacement generation resources given the quantity of retirements codified in various state and federal policy objectives. The power generation strategies proposed in the CAP could further exacerbate the shortfall of electric generation capacity in PJM and endanger the state's position as a net energy exporter.

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.

Overlooks the benefits of coal refuse energy and reclamation

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 emissions 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.

The CAP and GHG Inventory fail to recognize the GHG risk posed by coal refuse piles and the net emissions reductions from the remediation of these piles by coal refuse reclamation-to-energy facilities. Research conducted by TRC Environmental and the Lehigh University Energy Center in 2023 and shared with the Department show that the operation of these facilities in fact produce a net reduction of GHG emissions in PA. As noted in the TRC study, "combusting the same quantity of coal refuse permanently remediated by the coal refuse reclamation-to-energy industry in 2020 (5,546,818 tons) results in a net CO_2e reduction benefit of over a quarter billion net tons of lifecycle CO_2e emissions. Very simply, while the combustion of coal refuse does emit the greenhouse gas CO_2, doing so avoids the ongoing emissions of the potent greenhouse gas methane that would otherwise have been emitted during its extended lifecycle from that same amount of abandoned coal refuse in piles." The Lehigh study found, "when the full emissions profile of the coal refuse RTE industry is considered, including the reduction of emissions from reclamation of coal refuse piles, the coal refuse RTE industry produces a net reduction in GHG emissions. For a 20-year GWP cycle, the total offset amount of CO_2,eq is of the order of 0.13 to 0.58 billion tons."

Abandoned coal refuse piles located in PA frustrate local, national, and global efforts to achieve ambitious net zero greenhouse gas emissions goals, as well as disproportionately impacting residents of once thriving coal mining communities. It is well documented that abandoned coal refuse piles gradually emit uncontrolled and unregulated air pollutant emissions as long as such existing piles remain abandoned and, in many cases, "under the radar." While some air pollutants and GHGs are emitted at once during controlled combustion in a CFB boiler, those boilers incorporate best available control technology (BACT), are designed to achieve complete combustion of hydrocarbons, and are highly regulated by both state and federal air emissions requirements. Air emissions from abandoned coal refuse piles are not. Societal goals such as net zero GHG emissions by 2050 will be frustrated by this manmade source of nearly continuous "forever" emissions of methane unless abandoned coal refuse piles are also permanently remediated by then.

Absent the coal refuse reclamation-to-energy industry, legacy coal refuse piles would remain essentially abandoned to the environment and will frustrate regional air quality and climate change goals for multiple additional generations as the abandoned piles themselves continue to emit products of incomplete combustion, CO_2, and the potent greenhouse gas methane. These figures should be taken into account when calculating PA's GHG Inventory. Coal refuse reclamation-to-energy should be viewed at minimum as a carbon neutral if not a GHG reduction technology in the CAP.

Legislative Recommendations

The CAP recommends legislative updates to the Alternative Energy Portfolio Standards (AEPS) program and a state level carbon emissions fee alternative to the Regional Greenhouse Gas Initiative (RGGI).

Pennsylvania Reliable Energy Sustainability Standards (PRESS)

The AEPS was created in 2004 to encourage the development of alternative energy systems in PA. The program was implemented over a period of years culminating in 2021 with a requirement of 8% of energy from Tier I sources, including a 0.5% carve out from solar, and 10% from Tier II sources including waste coal. In 2017, legislation passed requiring alternative energy credits (AECs) meeting the solar carveout come from resources located in PA, while in 2020 the same requirement was added for Tier II AECs.

In 2024, Governor Shapiro proposed PRESS as an update to the AEPS. As proposed, PRESS would include several new resource types, add a third tier, and increase the amount of energy required to come from the three tiers to

50%, as well as create a new Zero Emissions Credit (ZEC) program for nuclear generation in PA. While an update to the AEPS may be warranted, as the targets have remained unchanged since 2021, as proposed PRESS creates an unachievable path for new resource development, relies on unproven technologies, and would cut support for existing environmentally beneficial energy sources.

PRESS adds resources such as Small Modular Reactors and Fusion Technology that are not yet commercially viable and clean hydrogen co-firing which is not commercially available at the scale needed for electricity generation. Additionally, the plan calls for 10% of retired Tier I credits to come from in-state resources beginning in 2030 and rising to 30% by 2050. In the 2022-23 compliance year, only 2% of retired Tier I AECs were generated by PA resources.

Perhaps most importantly, PRESS would reduce the Alternative Compliance Payment (ACP) to $35 from the current $45 for Tier II resources and sets an even lower $15 ACP for the new Tier III. The ACP serves as a de facto price cap on the credit market. A lower ACP will result in reduced support for Tier II and Tier III making these resources less competitive with surrounding states and less viable to continue their operations, particularly in a historically low-price PJM energy market.

The new PRESS Tier III would consist of waste coal, municipal solid waste, and integrated combined coal gasification technology (currently AEPS Tier II resources), generation of electricity utilizing by-products of the pulping process and wood manufacturing process (an AEPS Tier I resource), and add natural gas or coal using clean hydrogen (20%) co-fired blend or equivalent carbon intensity reduction. The proposed legislation calls for 3.8% of PA's energy to come from Tier III resources in 2025 rising to 5% in 2031. However, since at least 2020, proposed PRESS Tier III resources currently producing AECs in PA (waste coal, municipal waste, black liquor) have annually generated 5.5% of PA's energy. Therefore, even without any increase in generation, PRESS will have an initial 50% oversupply of Tier III credits. This oversupply, taken in conjunction with the 2/3 reduction to a $15 ACP, will produce a PRESS Tier III credit price far below the current $30 Tier I and Tier II AEC price and result in a significant cut in support for these environmentally beneficial energy resources.

At a time when PA and the PJM grid need clean, reliable alternative energy resources, the proposed PRESS Tier III could lead to the closure of waste coal, municipal waste, and wood pulping energy facilities in PA, as well as the attendant economic and environmental benefits.

Pennsylvania Climate Emissions Reduction Act (PACER)

Former Governor Tom Wolf announced in 2019 that PA would join the regional carbon credit trading program RGGI. In 2022, a final PA RGGI regulation was published based upon the model RGGI regulation with PA specific provisions, including a Coal Refuse Set Aside to hold the coal refuse reclamation-to-energy industry harmless under this program. In the final PA RGGI regulation, the Department set aside 12.8 million CO_2 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." The PA RGGI regulation was subsequently challenged by energy industry groups and legislators and the Commonwealth Court ruled that the administration did not have authority to enter RGGI without legislative authorization, which the Shapiro administration has since appealed to the PA Supreme Court.

Governor Shapiro proposed PACER as a state level alternative to RGGI. The PACER program would maintain the PA specific aspects the PA RGGI regulation, including the coal refuse set aside. This set aside is vital to protecting the continued economic viability of these environmentally beneficial EGUs should RGGI or PACER ever become effective in PA. The added cost of complying with the PACER program would increase operating costs for traditional fossil fuel EGUs, such as coal and natural gas, and impact the continued viability of these facilities in PA compared to those in PJM states without a carbon emissions trading program.

Conclusion

Climate change remains a critical concern facing our state, nation, and the world and Pennsylvania must do its part to address this important issue. However, in doing so, the state must act in a responsible manner to address our impact on the environment while still growing the economy and protecting jobs in our communities. Pennsylvania has unique environmental challenges and opportunities, including the largest number of polluting AML sites in the nation and a fleet of environmentally beneficial reclamation-to-energy facilities to address this issue, which should be taken into account as the state reviews and implements this plan to address our climate change impact.

I appreciate the opportunity to submit these comments on the 2024 CAP update. While the CAP provides valuable insight on the risks posed by climate change and useful tools for addressing them in Pennsylvania, I hope that Governor Shapiro, the General Assembly, and the Department will take the concerns raised in these comments into consideration before acting upon the strategies and recommendations proposed in the CAP.

Respectfully submitted,

Jaret A. Gibbons
Member, Climate Change Advisory Committee

COMMENTS ON 2024 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

September 2024

INTRODUCTION

As a member of the Climate Change Advisory Committee (CCAC), I appreciate the opportunity to share these comments and this response to the final 2024 Climate Change Action Plan (Action Plan or CAP) of the Department of Environmental Protection (Department or PA DEP).

There are several important areas where I diverge from 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.

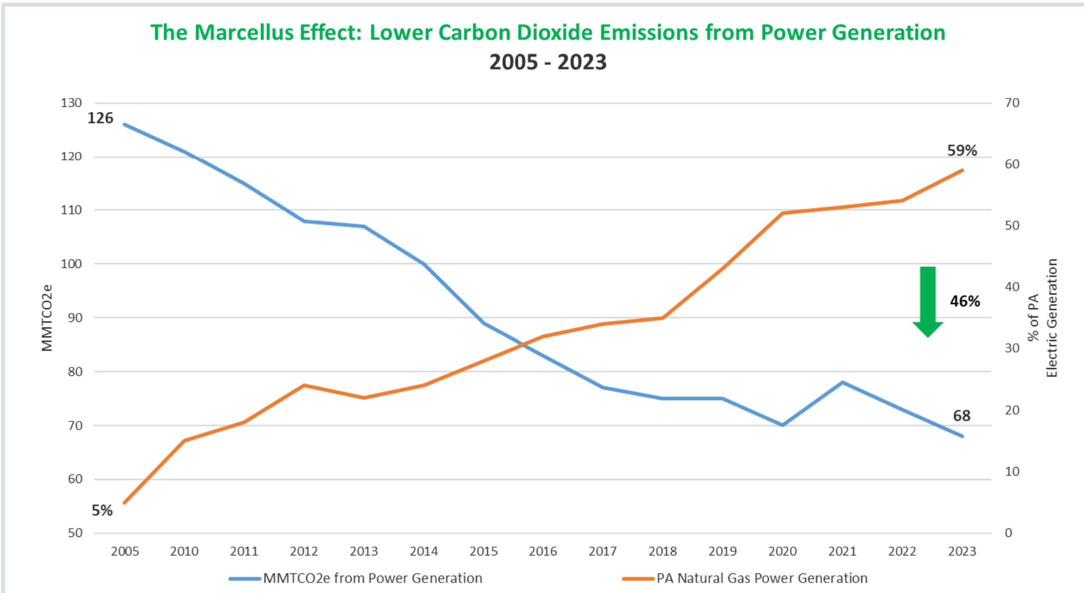
PENNSYLVANIA'S CURRENT GREENHOUSE GAS EMISSION PROGRESS

Notably lacking from the CAP is a substantive 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 both in the CAP and in day-to-day communication work of the agency 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]

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.

[1] Scant attention is paid to historical reductions of GHG emissions in PA on page 3 of the Executive Summary and later page 31. This explicit recognition – however fleeting – comes after generally being ignored in prior CAP reports.

In Pennsylvania, 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.

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:

[2] Source: U.S. Energy Information Administration
[3] Page 3 of the CAP Executive Summary warns of higher average temperatures, increased heat waves, saltwater encroachment up the Delaware River estuary, increased droughts, heavier, more severe rain events, inland floods and other impacts.

- 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]

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. However, 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 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. It is ironic that the Department asserts the need for all other states and jurisdictions to achieve similar emission reductions in order to stay below the 2-degree Celsius threshold but then seeks to advance policy goals which displace emissions and thus make it more difficult for other states.

[4] Page 14 of 2019 Climate Change Action Plan

SOMETIMES IT RAINS; SOMETIMES IT DOESN'T

It is disappointing that the CAP seems to assert that every disadvantage an individual or community may face is attributable, in some manner, to climate change. Or, if the circumstance is not attributable to climate change, then certainly the outcome or impact to that individual or community will be disproportionate…due to climate change.

The CAP and accompanying documents use phrases such as vulnerable population, or historic inequities, or just transition as if checking every box of a politically correct bingo card, while treating individuals and communities as if they are mere bystanders in their own existence.

Recognition of the impact human activity can have on our environment is important and impacts ought to always be minimized when feasible. However, 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. Countering this narrative 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. We never had it so bad before.

> *"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**
>
> **UPDATE: The world will now end in 6 ½ years.**

The media is obsessed with it, particularly those outlets which hold themselves out as independent news entities but are funded by large, anti-energy Foundations such as the Heinz Foundation, Parks Foundation and others. Headlines flood our social media and website clicks daily: "hottest month on record"; "driest month on record"; "wettest month on record". The climate-industrial complex is real, and it is funded by the foundations and our own taxpayer dollars.

Yet is this weather – and particularly its outcomes – really that extreme?

Without discounting the need to continue to improve upon the success to date, PA DEP should acknowledge that humankind 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:

[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

- 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 in progress attributable to affordable, domestic and abundant energy resources – energy resources which are now targeted for elimination under this CAP's recommended policies.

"CLEAN" ENERGY

The CAP uses the term "clean energy" 75 times throughout its narrative, with references to "clean energy" jobs,[6] electric generation sources, and taxpayer funding. This term is a misnomer, unfairly and inaccurately implying that anything which does not meet this narrow definition is "dirty" energy.

Toxic rare earth mineral sludge lake, Inner Mongolia. *Credit: Liam Young/Unknown Fields. Published www.bbc.com April 2, 2015*

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"

[6] The definition of "clean energy" jobs is, to put it mildly, overly generous. The Department's own past reports have categorized 50% of clean energy jobs as coming from the traditional and high-efficiency HVAC sector: 2020 PA Clean Energy Employment Report – https://files.dep.state.pa.us/Energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/2020EnergyReport/2020_PACEIR_FINAL_1.1.pdf

generation sources must be sufficiently backed up by traditional electric generation sources, typically coal, natural gas or nuclear.

Ironically, during a time when anti-fossil fuel advocates insist that fossil fuels be critiqued for impacts throughout their lifecycle (extraction to disposal), they reject the application of this very principle to those energy sources they seek to assert are "clean".

Every form of energy has impacts and implications. Gauging these impacts solely through the lens of carbon emission at the point of generation is myopic and frankly offensive to those engaged in important energy development that does not meet the vagaries of how DEP chooses to define 'clean' energy.

PACER and PRESS

I understand the Department's inclusion of these legislative initiatives because they were put forth by the governor. And I respect that prerogative. But that respect should not shy us away from an honest conversation about each.

First, PACER is essentially identical to the Regional Greenhouse Gas Initiative (RGGI). The only meaningful difference is the flexibility that legislation affords in spending the tax proceeds. However, from a functional standpoint, PACER is RGGI:

- It uses the same number of allowances as DEP authorized for RGGI.
- It permits allowances from RGGI to be recognized for compliance with PACER, and vice versa, essentially creating one homogeneous market price for an allowance, be it in PACER or RGGI.
- It does nothing to reduce actual CO_2 emissions; presuming the modeling done by DEP (at a cost of over $400,000 to ICF) reflects PACER, it will result in a 0.169% net reduction of CO_2 emissions. Not according to me; according to DEP.
- It allows a third-party entity, such as RGGI Inc., to manage the program, just like RGGI does.

In 2018, top climate scientist James Anderson warned that climate change would wipe out humanity – by 2023.

"The chance that there will be any permanent ice left in the Arctic after 2022 is essentially zero," Anderson said.

FACT CHECK: According to the Copernicus Climate Change Service, Arctic ice coverage in December 2023 was only approximately 3% less than the 1991-2020 average – and the Arctic had significantly higher ice coverage than was recorded in 2015.

The Department should simply be straightforward and acknowledge that PACER is about assessing and collecting a tax on carbon emissions, and then utilizing that revenue to invest in projects it believes have environmental benefits to the citizens of Pennsylvania. The presumption that this is about reducing CO_2 emissions and impacting climate change is a façade.

PRESS transforms the Commonwealth's Alternative Energy Portfolio Standards (AEPS) Act, which was never intended to be a vehicle to address climate change, into a de facto climate change bill. It micromanages the Commonwealth's electric generation portfolio by dictating a reliance on intermittent and unreliable energy resources, while displacing the one fuel source that has contributed the most to Pennsylvania's historic decline in carbon emission reductions over the past fifteen years: natural gas. In doing so, it threatens the lives of Pennsylvanians who depend on power on demand, in settings such as schools, hospitals, nursing homes and prisons let alone residences that depend on heating or air conditioning not just for comfort but for survival.

At a time when grid operators are sounding warnings over the lack of sufficient baseload electric generation to replace a historic trend in retirements, PRESS would severely accelerate these concerns while transforming Pennsylvania from the largest exporter of electricity in the nation to one dependent upon imports to meet its own electricity needs.

CAP Table 21 – Alterative Energy Programs for Neighboring States

DEP includes a table (Table 21) on page 220 of the CAP. This table is misleading in several areas:

- As the title implies, this is supposed to compare "alternative" energy programs among neighboring states. However, DEP only chose to include Tier 1 obligations in Pennsylvania, rather than reflect all the sources (and mandates) contained in Pennsylvania's AEPS Act. The correct percentage to be included is 18%.

- The chart states that Pennsylvania has a solar 'maximum' of 0.5%. This is factually inaccurate. Pennsylvania's AEPS requires a *minimum* of 0.5% solar be used by entities with a compliance obligation under the statute. This is a significant difference.

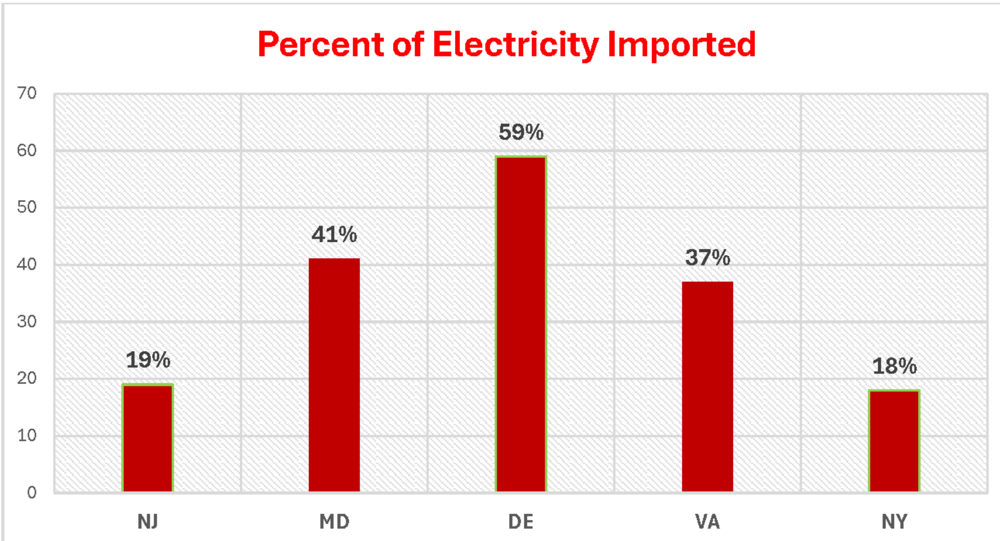
My concerns, however, are more substantive than the seemingly numerical representation issues above. The CAP states the following preceding Table 21:

> *"Additionally, New Jersey has a 100% by 2050 goal and Maryland has a 100% by 2035 goal. These goals are non-binding but provide a roadmap and a target toward complete decarbonization of the state's power sectors."*

A few things. First, these goals refer to in-state power generation, even though it is not stated in the above paragraph. Second, the assertion that these goals *"provide a roadmap and a target toward complete decarbonization of the state's power sectors"* is just absurd.

Just to be clear: according to DEP's rational, if a state only had solar and wind generation within that state and relied upon importing 95% of its electricity from fossil fuel power plants located outside of that state, that state will have achieved a 100% goal of complete decarbonization of its power sector.

So, let's look a little closer at the states DEP chose in Table 21 and their reliance upon out-of-state power generators to meet the electricity needs of their citizens:



The data above is based upon 2022 net generation as reported by the U.S. Energy Information Administration. It is worth noting that Maryland's reliance on electricity imports is anticipated to rise substantially should the Brandon Shores coal-fired power plant shut down in 2025.

TRANSPARENCY OF CONSULTING CONTRACT

Like past Climate Action Plans, the Department contracted with ICF Incorporated from Fairfax, Virginia to help prepare this CAP and associated documents. My understanding is that the total contract cost is between $400,000 and $500,000.

State law requires that contracts entered into by state agencies be posted online. I have raised this issue in past comment letters. The failure to post documents online for public consumption related to the expenditure of state tax dollars remains concerning. This failure is not limited to just this CAP. [7]

This may be viewed by some as 'inside baseball' and 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.

[7] 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 that fails to achieve any fair rendering of a commitment to transparency.

It is also concerning that part of the work performed by ICF was the development of suggested legislative recommendations related to climate change[8]. That is far beyond the scope of what a consultant should be doing. It is the responsibility of elected officials, including state administrative officials appointed by an elected Pennsylvanian, to suggest legislative recommendations, not a contractor. To have my own tax dollars used as part of this effort is even more disappointing.

Data Sources

In many areas of the CAP, it relies upon data sources that are multiple years old and for which current, updated data information is readily available. For example, much of the discussion on electricity generation and related emissions relies upon 2020 data. Yet, contemporary data including for 2023 is available from official government resources. Moreover, 2020 data is generally an anomaly (and to an extent, comparisons of 2021 data and emissions to 2020) due to the pandemic.

Conclusion

These thoughts, comments, observations and recommendations are mine and mine alone. I appreciate the time anyone has taken to read them.

[8] Under the "Acknowledgements and Disclaimer" section found on the 7th page of the document, it states "*DEP also developed the legislative recommendations included within this report*." While I do not question that DEP has developed and sanctioned the legislative recommendations found in the final report, it is clear that in earlier iterations of the report legislative recommendations crafted by ICF were included and discussed (and some ultimately discarded). It is the time and allocation of resources *during* the plan development process that I object to, not the inclusion of final recommendations by DEP. Acting DEP Secretary Shirley acknowledged as much regarding the role of ICF during the House Appropriations Committee public hearing held on February 28, 2024.

COMMENTS TO THE PENNSYLVANIA CLIMATE ACTION PLAN OF 2024

September 30, 2024

It was a pleasure to serve on the Pennsylvania Climate Change Advisory Committee and I appreciate the opportunity to submit comments on The Pennsylvania Climate Action Plan of 2024 ("Climate Action Plan").

The Climate Action Plan reads great in theory but is impractical and/or impossible to implement. Rather than analyzing each and every aspect of the Climate Action Plan, this letter will address high-level matters related to the Climate Action Plan.

Electric Grid Reliability, Potential Supply Shortages, and Increased Prices:

The Climate Action Plan promotes solar and other perceived environmentally friendly sources of energy, mostly renewable energy sources.[1] Further, the Climate Action Plan promotes policies that would most likely result in the shutting down and/or curtailment of operations associated with certain reliable sources of energy, specifically those sources associated with fossil fuels and other non-renewable energy sources that are used by base load power plants.

The Commonwealth of Pennsylvania is blessed with an abundance of natural resources, which for decades, the energy sector has used to generate electricity for the benefit of Pennsylvania together with exporting electricity to other states. Pennsylvanians have enjoyed a diverse energy portfolio, which has resulted in electric grid reliability, lower electric costs, jobs related to the energy sector and other economic and social benefits.

If the Climate Action Plan is implemented, it would result in Pennsylvanians losing the energy luxuries and benefits that Pennsylvanians currently enjoy. For example, the closing of certain power generation facilities would result in less electricity being generated even though demand for electricity is increasing; thus, resulting in higher electric prices. Further, implementation of the Climate Action Plan would result in Pennsylvania transitioning from constant, reliable sources of electricity generated from base load power plants to those energy sources that require ideal conditions; thus, resulting in less electric grid reliability. Moreover, the Climate Action Plan fails to address how the Commonwealth will make up for the loss of electricity

[1] It is noted that the Climate Action Plan does not address the social and environmental costs associated with the perceived environmentally friendly sources of energy. For example, the Climate Action Plan does not address the costs associated with the disposal of obsolete solar panels and environmental costs associated with the manufacturing of items related to these perceived environmentally friendly sources. Additionally and as an example, the solar industry is being driven by various incentives such as tax credits and other subsidies. The Climate Action Plan fails to address the social and economic harm to ratepayers and taxpayers in Pennsylvania as a result of these various incentives. Instead, the Climate Action Plan assumes that Pennsylvania taxpayers and ratepayers should absorb the heavy burden of promoting certain renewable energy sources.

generated from base load power plants, as renewable energy sources might not be able to produce electricity during an emergency and/or capacity event.

Electrification of the Grid:

The Climate Action Plan would result in greater electrification of the grid. 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 increased demand.

In addition, renewable energy sources (solar and wind) do not generate the same amount of energy as other sources of energy. For example, a solar farm requires 4 – 8 acres of real estate per megawatt (MW) of solar power. Other power generation facilities require less than 1 acre of real estate per megawatt (MW). Hypothetically, if a 1,500 MW coal fired power generation facility shuts down, it would take, at a minimum, a 6,000-acre solar farm to generate the same amount of electricity lost by the closing of a 1,500 MW coal fired power generation facility. Further, the coal fired power generation facility is a base load power plant. The Climate Action Plan fails to address how Pennsylvania will make up the power lost from the closure of base load power plants that use fossil fuels and how renewable energy sources would meet demand and capacity requirements during an emergency and/or another capacity event. Further, with future development, the electric needs in Pennsylvania will only increase and therefore, the demand for electricity will increase. However, the Climate Action Plan fails to account for how Pennsylvania will meet growing demand for electricity and continue to provide reliable electricity.

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 coal and other fossil fuels, which are used by base load power plants. The Climate Action Plan should address how the Commonwealth intends to provide sufficient electricity to meet the rising demand in electricity while at the same time, the Climate Action Plan, if implemented, would result in a decrease in the supply of reliable electricity. The potential economic and social costs to the ratepayers, taxpayers, and communities should be included in the Climate Action Plan.

Environmental Justice Communities:

The Climate Change Plan states as follows:

> "This 2024 CAP aims to serve environmental justice areas (EJ areas) which encompass a diverse range of Pennsylvania communities from rural areas, including coal towns, to dense urban areas." *Climate Action Plan, Page Introduction 12.*

However, implementation of the Climate Action Plan would have a devastating and adverse impact on various rural EJ areas.

Numerous rural EJ areas are centered around and/or rely upon a certain industry and/or entity for jobs, economic development, social needs and other related services. If the Climate Action Plan is implemented, these industries could cease to exist without any plan for new job opportunities and/or industries to come into these areas. Numerous EJ areas depend on industries that would be adversely affected by the Climate Action Plan and the Climate Action Plan does not properly account for the social and economic impacts to these EJ areas.

Industrial Sector:

The Climate Action Plan imposes certain carbon reduction requirements that are unachievable on various industries that require carbon as a key component of the manufacturing process. Further, the Climate Action Plan fails to recognize the efforts of certain industries in using new technologies to reduce carbon.

As stated above, the Climate Action Plan is good theory, but impractical to implement. Several industries that are critical to the nation's security and infrastructure depend on carbon as part of their manufacturing process. Without carbon, these industries would not be able to make certain products that are critical and necessary to our nation's security and infrastructure. Alternatively, these industries would be required to install costly technologies to meet the standards set forth in the Climate Action Plan, which again, and even if feasible to install and/or such technologies related to carbon capture even exist, will raise the costs to consumers.

Net Zero Grid:

The Climate Action Plan fails to address how a net zero grid would be able to meet the future demand for electricity in Pennsylvania. However, the net zero grid fails to account for certain industries such as the waste coal to energy industry, which are part of the reclamation process in Pennsylvania. The long-term benefits of the waste coal to energy industry are substantial when considering that these facilities are reclaiming legacy coal mining areas while producing reliable energy and serving as base load power plants. Further, this industry has substantial environmental benefits which have long been recognized in the Commonwealth.

Legislation Recommendations:

The Climate Action Plan sets forth legislative recommendations that are unrealistic and will increase costs, lower electric grid reliability and result in the loss of jobs. Specifically, the Climate Action Plan promotes the following two proposals: (i) Pennsylvania Reliable Energy Sustainability Standard ("PRESS"); and (ii) Pennsylvania Climate Emissions Reduction ACT ("PACER").

PRESS is a proposal that would overhaul the current Pennsylvania Alternative Energy Portfolio Standards Act ("AEPS"). AEPS, in its current form, is working as intended and has become an invaluable asset to certain industries. PRESS would eliminate the various tiers and establish new tiers. The proposed tier system of PRESS would have a devastating impact on the waste coal to energy industry's ability to continue to operate in its present form. PRESS, in its present form, must not be adopted until it addresses the needs of the vital waste coal to energy industry.

PACER is a restrictive proposal that would impact grid reliability and result in loss of jobs especially in rural EJ areas. The Climate Action Plan cites other similar state level cap-and-invest or cap-and-trade programs such as those in California, Massachusetts, and New York – all states that are vastly different than Pennsylvania. Pennsylvania is uniquely situated with vast natural resources to generate electricity and many areas, specifically rural EJ areas, depend on the mining and development of fossil fuels. Pennsylvania needs to strike a delicate balance with taking climate change measures, but also making sure that our industries and all areas continue to have economic and social opportunities. This proposed legislation would cause economic and social hardship to many regions of Pennsylvania.

Conclusion:

Climate change is a problem that is facing Pennsylvania together with the rest of the world. At the same time, Pennsylvania should also embrace its natural resources, its diverse energy portfolio, and its ability to be a net exporter of electricity. Instead of a plan that only sounds good in theory but not in practice, Pennsylvania should adopt an all-encompassing plan that takes measures to combat climate change but also preserves our industries, our economy, our jobs, our communities, and the livelihoods of Pennsylvanians.

Very truly yours,

Jason E. Kelso

September 26, 2024

Lindsay A. Byron, P.G.
Environmental Group Manager
Energy Programs Office
Department of Environmental Protection
Rachel Carson State Office Building
400 Market Street
Harrisburg, PA 17101

Re: 2024 Pennsylvania Climate Action Plan Update

Dear Ms. Byron, DEP, and interested parties,

First, I would like to thank Senators Comitta and Costa for my recent appointment to the Pennsylvania Climate Change Advisory Committee. Climate change is the defining challenge of my generation and, unfortunately, it is likely to be the defining challenge of my children's generation. I am grateful for the opportunity to contribute to the work of this critically important effort.

I congratulate the committee, DEP and their consultants on producing a document that is clear and comprehensive. The breadth of recommendations is impressive and reflects the many tools available to us in tackling this challenge. I appreciate the acknowledgement that we are already feeling the effects. The DEP has taken a clearheaded assessment of the probable impacts and has recommended actions that are sensible and necessary.

It is important to highlight that "...the strategies lead to net positive job impacts for the Commonwealth" and lead to a slight increase in state economic output compared to the business-as-usual case. I also appreciate the recognition of the interaction between energy efficiency and health. "Additionally, energy efficiency improvements can be highly connected to health improvements, especially in poor areas with dilapidated buildings. Implementation efforts could aim to address both climate impacts of the buildings sector and improve health outcomes..." The intersection of health and energy efficiency has the potential to facilitate major improvements in environmental justice while meeting our climate goals.

I offer several suggestions for issues I hope we can address in the next version of the plan.

- Strategy F3. Inactive and Marginal Wells "encourages producers to plug inactive and marginal conventional wells, significantly reducing statewide emissions while having nearly no appreciable impact on energy production." A number of approaches are proposed, but no legislative recommendation is made. The plan currently assumes that "only 25% of the abandoned wells will be plugged by 2050." I encourage the committee to assess the effectiveness of ongoing efforts and to include a legislative recommendation in the next plan if it is clear that existing efforts continue to fall short.
- The Plan states that "more reductions will be needed to meet both short (2030) and long (2050) term climate targets." If the committee knew now how to fill this gap, it presumably

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would have simply recommended additional actions, but while we do not know the exact solutions, I encourage us to consider the possible paths to full achievement of the goals. We may want to include a section dedicated to describing the uncertainties in the analysis, particularly those related to modeling future prices, load growth, and technologies. There is inherent uncertainty in cost and adoption curves, but some will be more impactful than others. The long-term target is 25 years away. If we had done this exercise 25 years ago, few would have predicted the incredible reductions in the cost of solar and batteries in that time. Few would have predicted the shale gas boom that nearly eliminated coal from the current electricity generation mix. What might we be underestimating in the current projections? I recommend inclusion in future iterations of greater discussion of uncertainties and possible, if unquantifiable, technological, cost, or social disruptions that would dramatically impact the plan for better or worse.

- I am pleased to see acknowledgement that "the state will need to coordinate with FERC and PJM to facilitate interconnection queue reforms to reduce delays and to coordinate transmission investments in the region." I hope the committee will focus significant attention on this issue as we develop the next plan. The impact of these delays and recent proposals to exclude energy efficiency from the forward capacity market run counter to the strategies in the Plan. They are a major threat to our ability to create a carbon-free grid and to a somewhat lesser extent to the goals of improving energy efficiency in buildings and improving industrial energy efficiency.
- The prior (2021) version of the CAP included a call for robust gas efficiency programs. The current CAP includes strategy "B3. Gas Efficiency in Buildings: Deploy gas efficiency in existing buildings." The current CAP also calls out the importance of delivered fuels in strategy "B4. Building Electrification, Deploy gas and fuel oil alternatives in existing buildings," but there is no legislative recommendation for creating programs to tackle the inefficient use of delivered fuels and gas. I encourage the committee to consider if one should be included in the next version.

While I serve on a number of boards and committees, the opinions in this letter are mine alone and do not represent the official position of the Keystone Energy Efficiency Alliance, the Elk Creeks Watershed Association, Warren Energy, LLC, the Efficiency Valuation Organization, or any other group.

As a new member of the committee, the 2024 update was largely complete prior to my involvement. I look forward to working with this impressive group on the next version.

Sincerely,

Kevin Warren, PE