Pennsylvania Climate Action Plan

Strategies and actions to reduce and adapt to climate change

2018

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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Acknowledgements and Disclaimer

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This report was prepared in response to the Pennsylvania Climate Change Act (Act 70 of 2008), which requires the DEP to develop an inventory of greenhouse gases (GHG) and administer a Climate Change Advisory Committee (CCAC), a voluntary registry of GHG emissions, and a Climate Change Action Plan. Revisions to the Action Plan are required every three years. The Pennsylvania CCAC provided input and feedback to the DEP and ICF for the preparation of this Plan. The CCAC is composed of 18 members plus 3 ”ex Officio members.”

This 2018 Climate Action Plan Update is the fourth iteration of the Pennsylvania Climate Action Plan and builds on the work the commonwealth has already done. Different than years past, this 2018 Update offers a plan that more comprehensively addresses the changing climate in Pennsylvania by focusing on both the impacts of climate change (adapting to the impacts of climate change) and the prevention or slowing of human-caused climate change (reducing greenhouse gas emissions that cause climate change).

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Acronyms, Abbreviations and Plan Terms

ACEEE	American Council for an Energy-Efficient Economy
AECs	Alternative Energy Credits
AEO	Annual Energy Outlook
AEPS	Alternative Energy Portfolio Standard
AFIG	Alternative Fuels Incentive Grant
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAQ	Bureau of Air Quality
BAU	Business as Usual
BBtu	Billion British Thermal Units
BOC	Building Operator Certification
BRT	Building Retuning Training
CAP	Climate Action Plan
CCAC	Climate Change Advisory Committee
CDC	Center for Disease Control
CGE	Computable General Equilibrium
CHP	Combined Heat and Power
CO_2e	Carbon Dioxide Equivalent
C-PACE	Commercial Property Assessed Clean Energy
CSA	Community Supported Agriculture
CSE	Cost of Saved Energy
CTE	Career and Technical Education
DCED	Department of Community and Economic Development
DCNR	Department of Conservation and Natural Resources
DEP	Pennsylvania Department of Environmental Protection
DEPA	Drive Electric PA Coalition
DG	Distributed Generation
L&I	Department of Labor and Industry
DOE	U.S. Department of Energy
DPI	Disposable Personal Income
DVRPC	Delaware Valley Regional Planning Commission

EDF	Environmental Defense Fund
EE	Energy Efficiency
EERE	Department of Energy, Office of Energy Efficiency and Renewable Energy
EERS	Energy Efficiency Resource Standard
EIA	Energy Information Administration
EPA	U.S. Environmental Protection Agency
EPO	DEP Energy Programs Office
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FEMA	Federal Emergency Management Agency
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GP	General Permit
GPS	Global Positioning System
GSP	Gross State Product
GWh	Gigawatt Hours
HVAC	Heating, Ventilation, and Air-Conditioning
ICC	International Code Council
IECC	International Energy Conservation Code
IGCC	Integrated Gasification Combined Cycle
IRC	International Residential Code (IRC)
LCOE	Levelized Cost of Electricity
LED	Light-Emitting Diode
LEED	Leadership in Energy and Environmental Design
LFG	Landfill Gas
LPG	Liquefied Petroleum Gas
MMT	Million Metric Ton
MOVES	EPA's MOtor Vehicle Emission Simulator
MT	Metric Ton
NGOs	Non-Governmental Organizations
NPV	Net Present Value
NREL	National Renewable Energy Laboratory

O&M	Operation and Maintenance
OSHA	Occupational Safety and Health Administration
P3	Public-Private Partnerships
PA	Pennsylvania
PAGHSP	PA Green & Healthy Schools Partnership
PEDA	Pennsylvania Energy Development Authority
PEMA	Pennsylvania Emergency Management Agency
PennDOT	Pennsylvania Department of Transportation
PennTAP	The Pennsylvania Technical Assistance Program
PUC	Pennsylvania Public Utility Commission
RAC	L&I Review and Advisory Council
RGGI	Regional Greenhouse Gas Initiative
SCC	Social Cost of Carbon
SEM	Strategic Energy Management
SEPTA	Southeastern Pennsylvania Transportation Authority
SIT	State Inventory Tool
SRF	State Revolving Fund
SWE	Pennsylvania Statewide Evaluator
UCC	Uniform Construction Code
USDA	U.S. Department of Agriculture
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compound
WWTP	Wastewater Treatment Plant
ZEC	Zero Emissions Credit

Plan Terms

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 (U.S. Climate Resilience Toolkit 2018).
Capital expenditure	Represents the money spent by the private sector in 2015 dollars.
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 2015 dollars.
Disposable personal income per household	Represents the total after-tax income, of individuals, available for spending or saving in 2015 dollars, normalized by the number of households in PA (obtained from the U.S. Census).
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 within Pennsylvania or other energy generation sources located in Pennsylvania facilities.
Energy expenditure savings	Reductions in end-use energy costs (fuels and/or electricity) in 2015 dollars realized in Pennsylvania's residential, commercial, industrial, and transport sectors.
Gross state product (GSP)	Measure of a state's output in 2015 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).
Maintenance and repair costs	Costs associated with upkeep in 2015 dollars. These costs encompass fixed operation and maintenance (costs independent of volume such as taxes, insurance, personnel and administration) and variable operation and maintenance (costs dependent on volume such as consumables, waste disposal and unscheduled repairs).
Mitigation	Reducing and stabilizing the levels of heat-trapping greenhouse gases in the atmosphere (NASA 2018).

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). ***Note:*** *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.*
Public expenditures	The money spent by the public sector as investments, subsidies, or rebates in 2015 dollars.
Program costs	Incentives and administrative expenses in 2015 dollars.
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 (U.S. Climate Resilience Toolkit 2018).

A Message from Governor Wolf

Climate change, created by increased greenhouse gas emissions, is the most critical environmental threat facing the world. Science indicates that just a 2 degrees Celsius rise likely will have potentially irreversible major consequences, including sea level rise, superstorms, and crippling heat waves.

In the absence of federal leadership, states and cities are taking action to reduce emissions and protect their communities, economies, infrastructures, and environments from the significant risks of a warming climate.

By executive order, I've set the first statewide goal to reduce greenhouse gas emissions in Pennsylvania. The commonwealth will work to achieve a 26 percent reduction of greenhouse gas emissions by 2025 and an 80 percent reduction by 2050, compared with 2005 levels.

I've also established the Green Government Council to ensure that state government offices lead by example to help achieve these goals. Agencies will work together to increase green and sustainable practices, while saving taxpayers money and creating jobs in Pennsylvania's clean energy economy.

Developed by a team of state agencies and partners, Pennsylvania Climate Action Plan 2018 is an outstanding example of such leadership. Fully 100 actions are recommended that all Pennsylvanians can take, together and individually, in the highest levels of state office, in our communities, on the shop floor, and at home. We must be proactive to protect quality of life and livelihoods today and for coming generations of Pennsylvanians.

Tom Wolf

April 2019

A Message from Secretary McDonnell

Pennsylvania Climate Action Plan 2018 marks 10 years since state law first required the Department of Environmental Protection to develop a climate plan and periodic updates. It builds on earlier versions to recommend the most effective strategies to reduce greenhouse gas emissions and protect our communities, economy, and environment from the significant impacts of climate change. For the first time, it also emphasizes the need to start adapting today, given temperature and precipitation shifts Pennsylvania is already experiencing.

The plan incorporates the latest state data, quantitative modeling, and national best practices to recommend 19 strategies and 100 actions that state and local government leaders can take to reduce greenhouse gas emissions and increase economic gains in Pennsylvania. Modeling showed that 15 actions, if started now, will achieve a 21 percent reduction in emissions by 2025.

Perhaps the biggest recommendation is this: An all-out team effort is needed. Governor Wolf's executive order on climate change requires state government offices to lead by example, taking measures well beyond current energy efficiency efforts. It's vitally important that legislative and local government leaders, business owners, community organizations, and citizens join in, deciding what they can do now to reduce emissions and protect quality of life in the state. Pennsylvania Climate Action Plan 2018 is the leading resource to inform those decisions.

To get an idea of actions your government agency, organization, farm, business, or household can take, I invite you to turn the page. For more guidance, please see the complete plan and more information on climate change at DEP's webpage.

April 2019

Executive Summary

The Pennsylvania Climate Change Act (Act 70 of 2008, or Act) provides for a periodic report on potential climate change impacts and economic opportunities for the commonwealth. The Act requires the Pennsylvania Department of Environmental Protection (DEP) to:

- Develop an inventory of greenhouse gases (GHG);
- Administer a Climate Change Advisory Committee (CCAC);
- Set up a voluntary registry of GHG emissions; and
- Prepare and update a Climate Change Action Plan. Revisions to the Action Plan are required every three years. This document is the third update to the original Climate Change Action Plan, which was issued by DEP in December 2009.

Why Does Pennsylvania Need a Climate Action Plan?

In recent years, extreme weather and catastrophic natural disasters have become more frequent and more intense. Like many parts of the United States, Pennsylvania is expected to experience higher temperatures, changes in precipitation, sea level rise, and more frequent extreme events and flooding because of climate change in the coming decades. Climate impacts in Pennsylvania are already occurring and put Pennsylvanians and local industries at risk. Key impacts include:

- More frequent extreme weather events, including large storms, periods of drought, heat waves, heavier snowfalls, and an increase in overall precipitation variability, with increased infrastructure disruption and need for emergency management.
- Increased risks of injury and death from extreme weather events.
- Increased human health risks from air pollution, diminished water quality, and heat stress such as exacerbated asthma or increased water-borne illnesses.
- Changing pest, weed, and disease management challenges for farmers and livestock producers.
- Increased demand for energy, particularly during warmer summer months, meaning higher energy costs for consumers and increased strain on the grid to provide reliable power.
- More frequent flooding and associated disruptions due to sea level rise in communities and cities in the Delaware River Basin, including the city of Philadelphia.
- Potential for wetland drying in the Ridge and Valley ecoregion, resulting in loss of habitat for multiple wetland-dependent species, including many birds, frogs, salamanders, fish and fur-bearing mammals.
- Changing conditions for plant and animal species, with economic impacts to the timber industry, hunting, and fishing industries, and ecotourism.
- Changes in rainfall, snowfall, heat, and other conditions that will affect outdoor recreation, transportation, and general use of the outdoors.

- Potential for degraded water quality in the tidal freshwater portion of the Delaware estuary.

These impacts could alter the many fundamental—but often not explicit—assumptions about climate that are intrinsic to the commonwealth's infrastructure, governments, and businesses. Estimates indicate that recent extreme events alone have cost governments (leaders), citizens, and businesses in the United States more than $1.1 trillion since 1980. Climate change can also affect vital determinants of health such as clean air, safe drinking water, sufficient food, and secure shelter. Health impacts from climate change are expected to cause around 250,000 additional deaths globally per year between 2030 and 2050, as well as additional direct damage costs estimated to be around $2-4 billion per year by 2030.

Based on decades of research and evidence, it is widely accepted that these events are highly likely a result of climate change caused by human activities. Therefore, it is critical that leaders, citizens, and businesses in the Commonwealth of Pennsylvania:

- Consider how Pennsylvania's climate may change in the future;
- Understand what (if any) impacts would occur if those changes are not addressed; and
- Take action to adapt to the changes and reduce the GHG emissions that are causing them, while making the economy stronger and meeting the needs of all Pennsylvanians.

Plan Goals and Targets

The Commonwealth of Pennsylvania's government has already been leading on climate action through a series of activities, including: executive action, legislative action; planning, research, and information gathering; and program implementation. In particular, Governor Wolf has been leading Pennsylvania's efforts to combat climate change, which he calls the most critical environmental threat confronting the world. In January 2019, Governor Wolf signed Executive Order 2019-01 "Commonwealth Leadership in Addressing Climate Change and Promoting Energy Conservation and Sustainable Governance" which states that Pennsylvania shall strive to reduce net greenhouse gas emissions 26 percent by 2025 from 2005 levels, and 80 percent by 2050 from 2005 levels, among other initiatives and goals. Governor Wolf's leadership, initiatives, and focus on climate change is fully consistent with the goals and targets in this Action Plan.

More specifically, this 2018 Climate Action Plan Update comprehensively considers the changing climate in Pennsylvania by addressing both the impacts of climate change ("adaptation" to climate impacts) and the causes of climate change (reducing and stabilizing greenhouse gas emissions, or "mitigation").

Goals: To ensure the effectiveness of this Plan, overarching adaptation goals and emissions reduction targets are used to frame the strategies. This Plan identifies two adaptation-focused goals, which can be achieved by actions from citizen, businesses, and leaders in the commonwealth:

- Minimize disruptions to Pennsylvania's citizens, economy, and environment from climate-related hazards.
- Increase Pennsylvania's ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from climate-related disruptions.

Targets: Meanwhile, the mitigation targets used in this Plan for gauging the results of a set of potential GHG reduction strategies are similar to Governor Wolf's targets for the commonwealth:[1]

- 26 percent reduction of net GHG emissions by 2025, from 2005 levels
- 80 percent reduction of net GHG emissions by 2050, from 2005 levels

If all states achieved similar GHG reduction targets, and other nations met comparable goals, climate science analysis suggests that global temperature rise could be kept below the 2-degree Celsius threshold cited by experts as the level beyond which dire consequences would occur, including sea level rise, superstorms, and crippling heat waves.

In addition to the above goals and targets, and per Act 70 of 2008, cost-effectiveness is also a key factor in strategy selection.

GHG inventory: As required by the Pennsylvania Climate Act, DEP must prepare a greenhouse gas emissions inventory annually. This statewide GHG inventory serves as the basis for the statewide reductions called for in Governor Wolf's Executive Order 2019-1 "Commonwealth Leadership in Addressing Climate Change and Promoting Energy Conservation and Sustainable Governance."

The statewide GHG inventory is generated using the U.S. Environmental Protection Agency's (EPA) State Inventory Tool (SIT). The Inventory includes all emissions from the residential, commercial, industrial, transportation, electricity production, agriculture, waste management, forestry, and land use sectors. In 2015, the most recent data available, total statewide emissions in Pennsylvania were 287 $MMTCO_2e$ while net emissions (accounting for emissions sinks from forestry and land use) were 257 $MMTCO_2e$. These emissions have been reduced since 2005, when total statewide emissions were 326 $MMTCO_2e$ and net emissions were 291 $MMTCO_2e$.

Recent emissions reductions have occurred primarily due to a shift in the electricity portfolio mix and energy efficiency measures. Since 2005, Pennsylvania's electricity generation has shifted from higher carbon-emitting electricity generation sources, such as coal, to lower and zero emissions generation, such as natural gas, wind and solar energy. At the same time, overall energy use in the residential, commercial, transportation, and electric power sectors has been reduced.

	2005 actual	**2015 actual**	**2025 target**	**2050 target**
Net Emissions (MMTCO2e)	291	257	215	58
Difference (MMTCO2e)		34	76	233
Percent Change		12%	26%	80%

[1] This Action Plan analyzes the targets on a consumption-based model to determine the amount of greenhouse gas emissions reduced from mitigation strategies. The target included by Executive Order 2019-1 is established for reductions to all greenhouse gases emissions generated in Pennsylvania, including those from energy that is exported to other states.

DEP prepares and updates the statewide greenhouse gas inventory annually, as information becomes available.

How this Plan was Developed

The strategies in this report reflect an iterative process between the DEP Energy Programs Office, Bureau of Air Quality, and Policy Office; their sister agencies (the Pennsylvania Departments of Conservation and Natural Resources (DCNR), Agriculture, Community and Economic Development, Health, Transportation, General Services, Pennsylvania Emergency Management Agency, and Pennsylvania Public Utility Commission); the Climate Change Advisory Committee; and other stakeholders. More specifically, DEP's process included the following steps:

1. DEP, with the support of the analysis team (ICF), separately identified strategies with adaptation benefits and strategies with emissions reduction benefits. DEP and the analysis team iteratively prioritized and integrated the strategies, prioritizing those with both adaptation and emissions reductions benefits.
2. DEP and the team refined the list of strategies based on sister agency and CCAC feedback, and selected strategies and actions to quantitatively model to estimate GHG reductions, cost-effectiveness, and other effects. Strategies were selected for modeling based on an initial screen of potential contributions to GHG reductions—strategies that were expected to result in larger GHG reductions were quantitatively assessed. Most of the quantified strategies focus on clean energy, consistent with the majority of emissions (88 percent in 2015) in Pennsylvania resulting from energy production and consumption.
3. DEP and the analysis team then conducted modeling for selected strategies for GHG, energy, and micro-economic effects.
4. Macro-economic modeling (e.g., changes in jobs) for each strategy was conducted using the REMI PI+ model.
5. Lastly, DEP and the analysis team outlined additional specific actions within each strategy for leaders, citizens, and businesses, and specified implementation steps for modeled actions.

Plan Sectors, Recommended Strategies, and Actions

Sectors: The Plan is organized by and addresses eight sectors:

- Energy Consumption
- Energy Production
- Agriculture
- Ecosystems and Forestry
- Outdoor Recreation and Tourism
- Waste Management
- Water Resources
- Human Health

Recommended Strategies: Within each sector, the Plan identifies sector-specific climate change impacts, as well as one or more strategies to adapt to climate change impacts and reduce emissions within that sector. Altogether, the Plan identifies 19 strategies, as follows:

- Increase end use energy conservation and efficiency
- Implement sustainable transportation planning and practices
- Develop, promote, and use financing options to encourage energy efficiency
- Increase use of clean, distributed electricity generation resources

- Create a diverse portfolio of clean, utility-scale electricity generation
- Reduce impacts of fossil fuel energy production and distribution
- Increase production and use of alternative fuels
- Use agricultural best practices
- Provide resources and technical assistance to farmers to adapt
- Protect ecosystem resilience, including forest systems where species will shift
- Monitor, identify, and address ecosystem vulnerabilities
- Help the outdoor tourism industry manage shifting climate patterns
- Reduce and use waste sent to landfills
- Use stormwater best management practices
- Promote integrated water resources management and water conservation
- Improve reliability and accessibility of public information about climate-related health risks
- Bolster emergency preparedness and response
- Lead by example in commonwealth and local government practices and assets
- Incorporate historical and projected climate conditions into siting and design decisions for long-term infrastructure

Recommended Actions: Each strategy encompasses multiple actions—specific policies, programs, or activities for state and local leaders (i.e., government), citizens, and businesses. The strategy descriptions include lists of these specific leadership, citizen, and business actions, as well as information on strategy benefits and costs, including climate resilience, environmental, and economic benefits and costs.

The Plan explicitly models the benefits and costs for 15 leadership actions within seven of the strategies, ones deemed the most impactful in reducing GHG emissions, as listed below.

- Increase end use energy conservation and efficiency
    - Update building codes
    - Increase adoption of energy efficiency, and expand Act 129
    - Create an Act 129-like conservation and efficiency program for natural gas
    - Expand energy assessments and provide more trainings on energy efficiency for industry
- Implement sustainable transportation planning and practices
    - Reduce vehicle miles traveled for single-occupancy vehicles
    - Implement a strategic plan and incentives for increasing electric vehicle use
    - Increase the use of clean public transportation through electric municipal bus fleets
- Increase use of clean, distributed electricity generation resources
    - Invest in and promote building-scale solar
    - Incentivize and increase use of combined heat and power (CHP)
- Create a diverse portfolio of clean, utility-scale electricity generation
    - Increase Alternative Energy Portfolio Standard (AEPS) Tier 1 targets, and further increase in-state generation and use of renewables
    - Implement policy to maintain nuclear generation at current levels
    - Limit carbon emissions through an electricity sector cap and trade program

- Reduce impacts of fossil fuel energy production and distribution
    - Implement policies and practices to reduce methane emissions across oil and natural gas systems
- Increase production and use of alternative fuels
    - Increase recovery and use of gas from coal mines, agriculture, wastewater, and landfills for energy
- Use agricultural best practices
    - Increase adoption rate of and provide training for no-till farming practices

In addition, the Plan includes nearly 100 additional leadership actions that were not quantitatively modeled, but that can help the commonwealth to reduce GHG emissions, adapt to the changing climate, and reduce the risks of climate impacts. Examples of these types of actions include:

- Expand home weatherization programs
- Support community solar legislation and develop model local ordinances
- Expand integrated farm management and conservation planning
- Promote forest conservation, reforestation and urban tree canopy expansion
- Implement programs to encourage citizens and business to reduce waste (including food waste) and use recycling and composting programs through reduce, reuse, and recycle actions
- Review existing emergency response, preparedness, evacuation, and management plans
- Incorporate climate change considerations into decision making processes and criteria
- Develop or update floodplain mapping using the best available science and accounting for the impacts of climate change

Because climate change is a universal issue that effects everyone, leadership, citizens, and businesses must all play a role in reducing GHG emissions and adapting to climate change impacts. Therefore, in addition to the leadership actions, this Plan separately identifies dozens of actions that citizens and businesses could take to advance climate action.

Benefits and Costs for Modeled Strategies and Actions

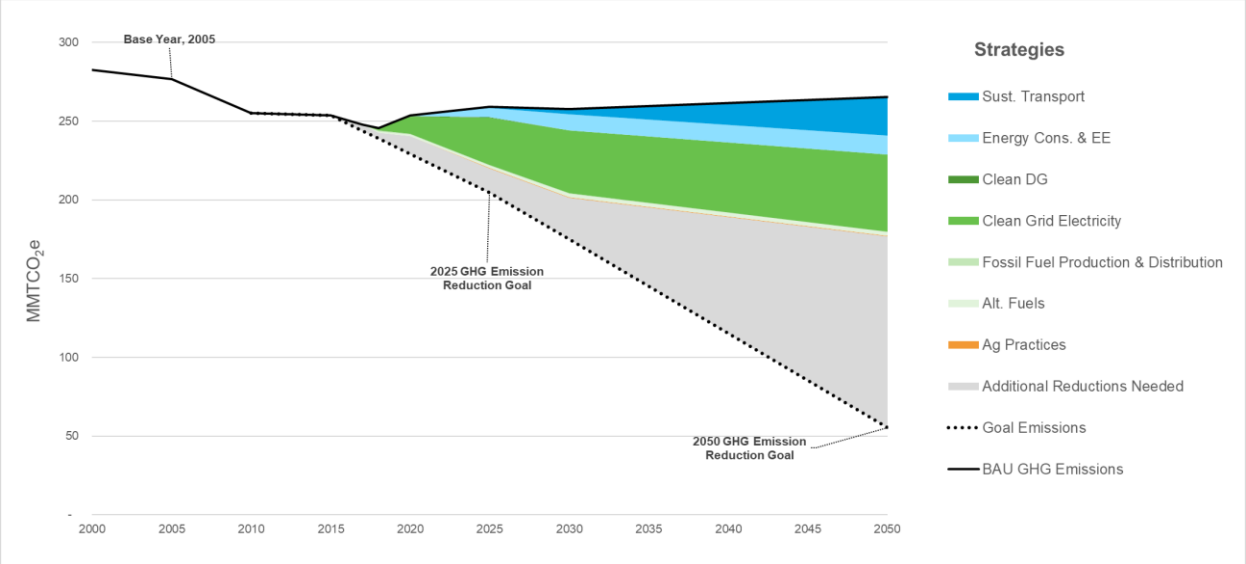
The Plan summarizes the benefits and costs of the 15 quantitatively analyzed actions. Notably, the modeled actions in this Plan represent only a subset of the potential actions under a subset of the identified strategies. In other words, the benefits and costs of the quantified actions do not comprehensively account for all the strategies and actions identified in the Plan. If Pennsylvania pursues actions and strategies beyond those that were quantitatively assessed, there would be additional benefits and costs from both reducing GHG emissions and adapting to climate change. In addition, if the commonwealth pursues the quantified strategies and actions in a different way than the team assumed, the benefits and costs will differ from this analysis.

The benefits and costs of the 15 quantified emissions reduction actions are compared to 2005 GHG emission levels and further compared to a business as usual (BAU) scenario in which emissions are projected through 2050 to show the GHG benefits over time. In the BAU scenario, annual GHG emissions in 2050 are expected to be about 5 percent higher than annual GHG emissions in 2015, but about

4 percent lower than emissions in 2005. As shown in Figure 1, the 15 quantified actions significantly reduce GHG emissions compared to the BAU scenario and are expected to result in:

- A 21 percent decrease in annual GHG emissions in 2025 as compared to 2005 levels; and
- A 36 percent decrease in annual GHG emissions in 2050 as compared to 2005 levels.

Figure 1. GHG Reductions Through 2050 for All Strategies, Grouped by Sector



The results from the 15 quantified emission reduction actions fall short of meeting the modeling targets of 26 percent (2025) and 80 percent (2050) relative to 2005 GHG emissions. These findings are consistent with results in other jurisdictions—actions with large GHG reduction potential, such as those quantified for this Plan, are not enough to meet 2025 or 2050 targets, additional reduction steps will be needed as well.

For example, the America's Pledge report, *Fulfilling America's Pledge: How States, Cities, and Businesses are Leading in the United States to a Low Carbon Future,* shows that implementation of ten key climate actions—which are, for the most part, similar to what was modeled for this Plan—will likely result in a 21 percent reduction of annual GHG emissions in 2025 as compared to 2005 levels for America's Pledge, U.S. Climate Alliance, and Climate Mayors participants.

This finding further emphasizes the need for more ambitious and quick climate action from all actors, including leadership, businesses and citizens. This is particularly relevant for 2025 when there is less uncertainty than 2050 and more visibility into potential implementable actions.

While considering results, it is worth noting:

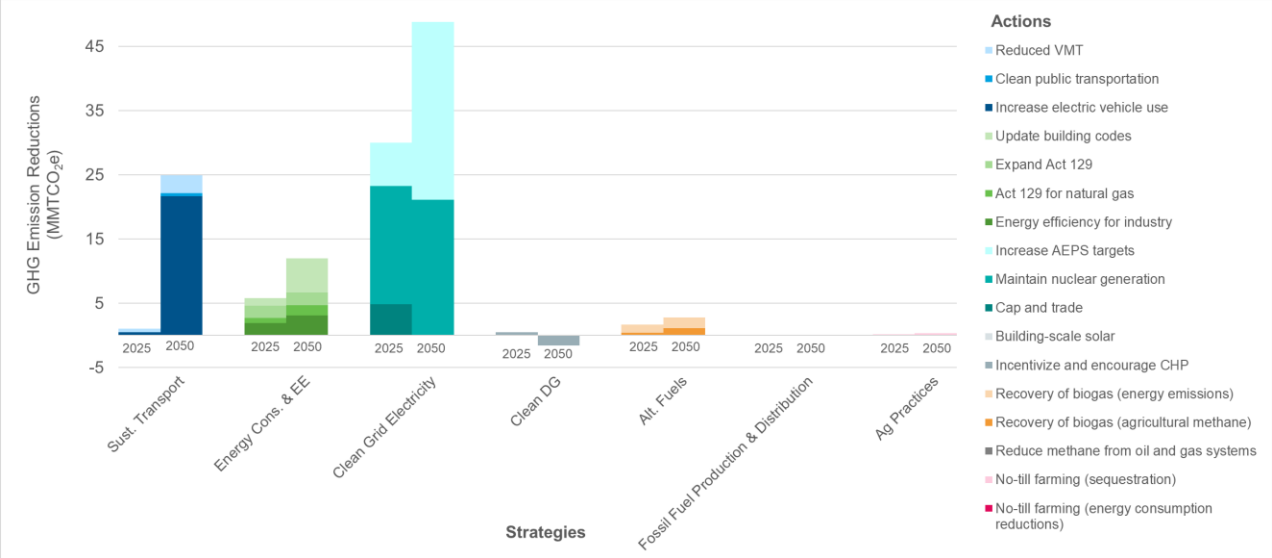
- As highlighted above, due to resource and time constraints, the modeling conducted for this report only focuses on a subset of strategies and actions that could reduce GHG emissions in Pennsylvania. Additional strategies and actions qualitatively addressed in this report would likely result in additional GHG reductions. For example, sequestration of carbon through forests offers a lot of capacity for GHG reductions in Pennsylvania. State forestlands, which include 2.2 million

acres of forest in Pennsylvania, currently sequester 5.14 million standard tons of carbon, and are on an upward trend. Extrapolating the carbon sequestration rate to all of Pennsylvania's forested lands, which include 17 million acres, is difficult, since they are managed differently and would exhibit different rates. Effective conservation and management of forests through programs such as the Nature Conservancy's Working Woodlands program can help accelerate and maintain forests as carbon sinks. This program has protected over 62,000 acres and accelerated restoration on 5,000 acres in Pennsylvania alone, with the result that almost 3.5 million tons of carbon will be sequestered over the life of the projects.

- The results do not consider new or updated federal policies that reduce GHG emissions.
- There are high levels of uncertainty associated with forecasting GHG emissions through 2050. Although this analysis provides single estimates of GHG emissions reductions from the quantified strategies, it would be useful to conduct sensitivity analyses that examine a range of aggressiveness for underlying modeling assumptions (e.g., market penetration rates or costs of certain technologies).

Figure 2 shows the GHG emissions reductions of each quantified action within the seven quantified strategies in both 2025 and 2050. As seen, the strategy to create a diverse portfolio of clean, utility-scale electricity generation has the most significant emission reduction impacts in both 2025 and 2050. Large GHG reductions are seen for energy conservation and efficiency measures in both 2025 and 2050, while the benefits of sustainable transportation measures do not really come into play until after 2025. While relative reductions from the other strategies are smaller, they still play a vital role in overall GHG reductions that could be achieved by implementing this Plan.

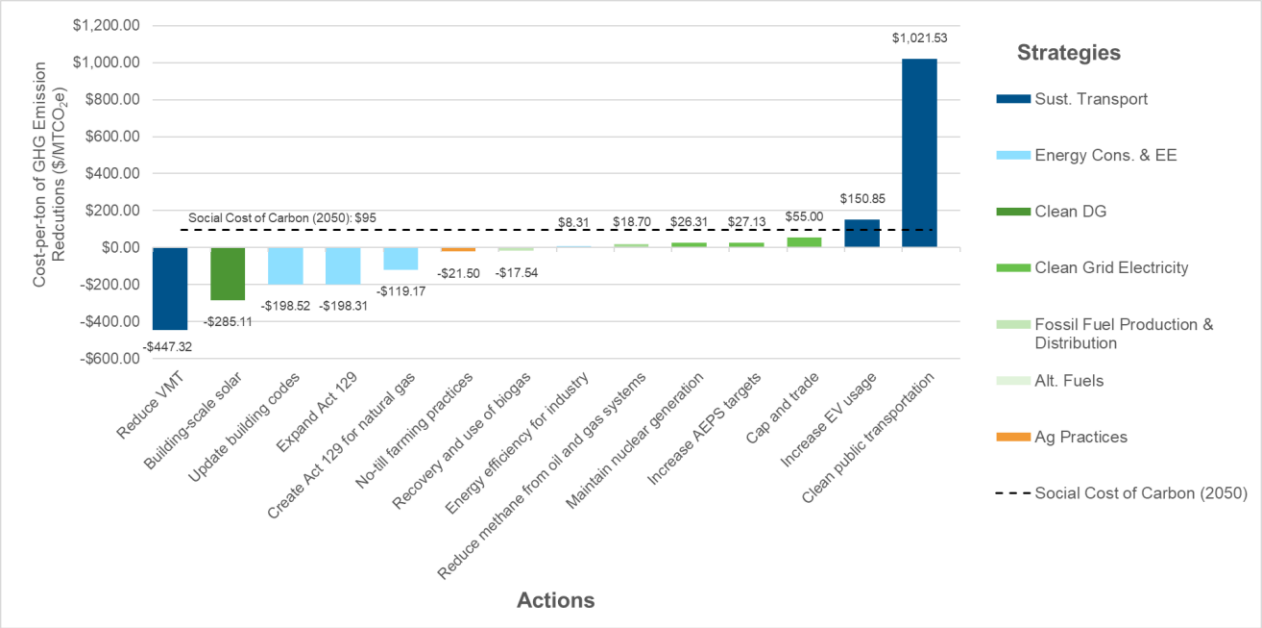
Figure 2. Annual GHG Reductions Compared to BAU for All Quantified Strategies and Actions in 2025 and 2050



To assess cost-effectiveness, the team looked at multiple factors which, when considered together, can be used to understand the cost-effectiveness of a strategy. Cost-effectiveness measures assessed include:

1. **Net present value (NPV)**, provided for each strategy action, which is a narrow analysis of direct costs and benefits, and uses zero NPV as a benchmark. This is useful as a simple microeconomic perspective. NPV does not include externality costs, such as those of GHGs or other emissions. 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.
2. **Cost per ton of CO_2e,** provided for each strategy action, which uses the social cost of carbon ($95) as a benchmark. Anything that falls below the benchmark could be considered cost-effective based on one perspective. This is useful as a climate policy perspective (see Figure 3)
3. **Macroeconomic factors** (described below), which captures multiple benefit and cost effects, including employment, gross state product, and personal income. This is useful as a richer set of indicators.

Figure 3. Cost per Ton of CO_2 Reduced for All Actions, By Sector ($/MTCO$_2$e)



1. Blue shading indications emission reductions from strategies within the Energy Consumption sector; green shading indicates emission reductions from strategies within the Energy Production sector; and orange shading indicates emission reductions from strategies within the Agriculture sector.

2. The Social Cost of Carbon (SCC) included in this analysis is the 2050 SCC assuming a 2.5% discount rate (EPA 2016). The EPA presents a range of SCC for 2050 between $26-$212, adding that the IPCC states the SCC estimates omit various impacts that would likely increase damages. The models used to develop SCC estimates do not currently include all of the impacts of climate change. Therefore, the $95 amount was selected for this analysis as a reasonable and accurate assumption.

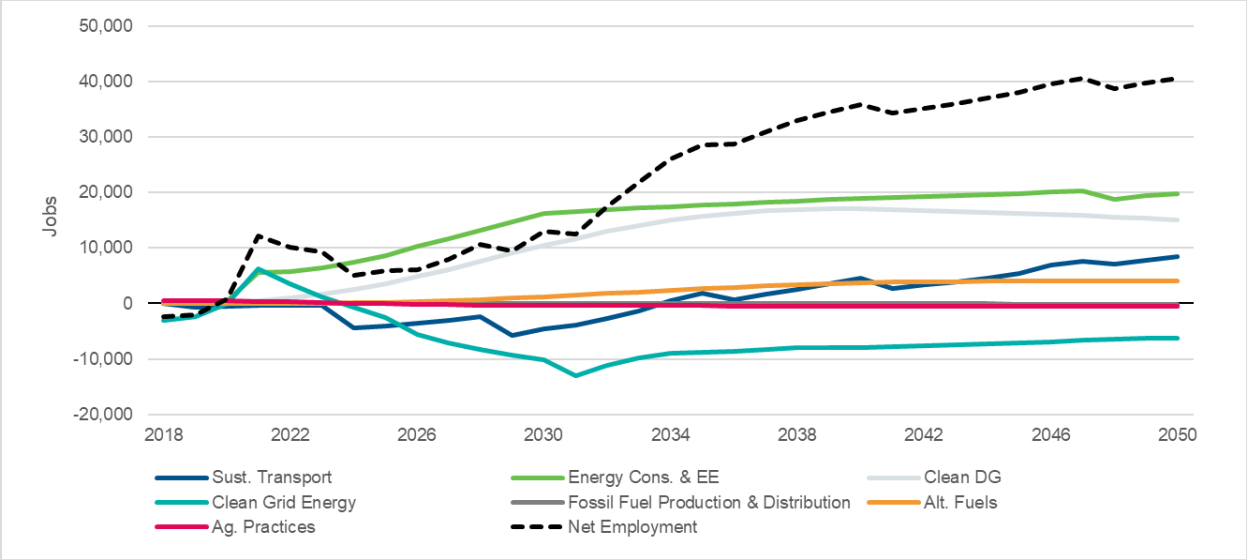
To achieve an understanding of the macroeconomic impacts of the Climate Action Plan (CAP), DEP and the analysis team examined the impacts on employment, gross state product (GSP), and personal

disposable income for commonwealth residents. The overall net impacts of the CAP strategies on the Pennsylvania economy are positive. For example, if just the 15 quantified actions were implemented, approximately 40,000 jobs would be created in 2050.

Figure 4 shows the number of estimated jobs supported through 2050 if all quantified actions are implemented for each of the seven quantified strategies. The trendlines by strategy are similar for GSP and personal disposable income, with the following net total results across strategies:

- **By 2050, Disposable Personal Income will be increasing $2.35 billion annually.**
- **By 2050, Gross State Product will be increasing $3.76 billion annually.**

Figure 4. Number of Annual Jobs Supported Through 2050, by Strategy



In aggregate, the suite of strategies recommended in this Plan maximize GHG reductions and are cost-effective for Pennsylvania. However, DEP, other agencies, and the Pennsylvania state legislature will need to prioritize and phase strategy implementation for both the quantified and non-quantified strategies in this Plan. The year 2025 is rapidly approaching and actions with large GHG and economic benefits and relatively low cost and political barriers offer Pennsylvania the best short-term solutions. In parallel, initiating actions that may take more time and resources to implement and have more trade-offs to consider will help Pennsylvania maximize the potential impact of this Plan.

Energy conservation and efficiency actions appear to be likely candidates for immediate implementation when looking at Figure 2, Figure 3, and Figure 4. These actions offer relatively large GHG reductions over time, provide cost savings (negative cost-per-ton of GHG reduced), and support growth in jobs. Many of the energy conservation and efficiency actions outlined in this Plan build upon existing Pennsylvania policies and programs that have widespread support, so they also offer a low barrier for implementation. Furthermore, many of these actions have important resilience benefits.

The case for sustainable transportation practices gets more compelling as time goes on. Considering Figure 2, Figure 3, and Figure 4, most of the GHG benefits of this strategy come after 2025, positive job results are not seen until 2030, and the costs of reductions for actions under this strategy are relatively

high compared to other actions. Nonetheless, state and local governments need to act now to realize the eventual benefits of this strategy and ensure infrastructure and policies are in place to drive and support market transformation. This will take time as the strategy will require public and private investment, scaling of infrastructure (e.g., bike shares and electric vehicle charging), and changes to consumer behavior to achieve the projected large climate and economic benefits through 2050.

Creating a diverse portfolio of clean, utility-scale electricity generation presents the most important trade-offs to consider. This strategy has an impact on almost every sector of the Pennsylvania economy, as well as residents, businesses, and government. The creation of clean utility-scale generation results in some possible negative net macroeconomic impacts, due to the multiple effects on Pennsylvania's generation mix and related energy industries. However, as shown in Figure 2, this strategy drives the largest reductions in GHG emissions of all the modeled strategies. Additionally, it has positive resilience impacts and appears to be cost-effective when considering the cost-per-ton of GHG reduced as compared to the social cost of carbon (see Figure 3).

Energy conservation and efficiency, sustainable transportation, and clean electricity generation are some of the most beneficial and impactful strategies that the commonwealth could pursue. However, as noted, the strategies quantified in this Plan provide only a starting point for significant GHG emission reductions. Additional actions will be needed in order to prevent catastrophic and irreversible climate change.

The impacts of climate change are real and will continue to put Pennsylvanians at risk from increased flooding, higher temperatures, and more. If not properly accounted for, these trends will threaten Pennsylvania in other ways: agriculture will have to adapt to greater extremes in temperature and precipitation; forests will be subject to multiple stressors; suitable habitat for plant and wildlife species is expected to shift to higher latitudes and elevations; winter recreation will decline; and public health will deteriorate because climate change will worsen air quality relative to what it would otherwise be, causing increased respiratory and cardiac illness.

These impacts can be alleviated if the actions in this Plan are adopted, but leaders cannot be the only ones who act. All Pennsylvanians–including citizens, businesses, and leaders–need to consider each action presented in this Plan as part of their responsibility to combat and adapt to climate change. The benefits of acting include economic growth, jobs, cleaner air, resilience and more. If Pennsylvanians want to provide a prosperous commonwealth with clean air, water, and land for generations to come, now is the time to take action on climate change.

1 Why Does Pennsylvania Need a Climate Action Plan?

In recent years, extreme weather and catastrophic natural disasters have become more frequent and more intense. Like many parts of the United States, Pennsylvania is expected to experience higher temperatures, changes in precipitation, sea level rise, and more frequent extreme events and flooding over the next century (Shortle et al. 2015, Horton et al. 2014). Based on decades of research and evidence, it is commonly accepted that these events are highly likely a result of climate change caused by human activities and specifically emissions of greenhouse gases (GHGs) (IPCC 2014).

Since the early 20th century, temperatures have already increased by more than 1.8°F (Shortle et al. 2015). If GHG emissions aren't curtailed significantly, the commonwealth is projected to be approximately 5.4°F warmer by 2050 than it was at the end of the 20th century (Shortle et al. 2015). Similarly, average annual precipitation in Pennsylvania has increased by approximately 10 percent over the past 100 years and, by 2050, it is expected to increase by 8 percent, with a 14 percent increase during the winter season (Shortle et al. 2015). Global average sea level, which has risen by about 7–8 inches since 1900 (with about 3 inches of that increase occurring since 1993), is expected to rise at least several inches in the next 15 years and by 1–4 feet by 2100 (USGCRP 2017).

Climate Change Impacts Already Happening

Climate change has had and will continue to have significant impacts. For example:

In Pennsylvania

- Temperatures increased by more than 1.8°F since the early 20th century and are expected to increase by an additional 5.4°F by 2050.
- Annual precipitation has increased by approximately 10 percent since the early 20th century and is expected to increase by another 8 percent by 2050.

In the United States

- Extreme weather events have cost a total of $1.1 trillion collectively since 1980.
- More extreme events such as Superstorm Sandy can have significant costs (e.g., $65 billion) individually.
- Annual losses in some sectors are projected to reach hundreds of billions by the end of the century.

Globally

- Sea level has risen 7-8 inches since 1900 (with half of the increase since 1993) and is expected to rise 1-4 feet by 2100.

Climate impacts in Pennsylvania are happening now and will continue to put Pennsylvanians and local industries at risk. Key impacts in Pennsylvania (Shortle et al. 2015) include:

- More frequent extreme weather events, including large storms, periods of drought, heat waves, heavier snowfalls, and an increase in overall precipitation variability, with increased infrastructure disruption and need for emergency management.
- Increased risks of injury and death from extreme weather events.

- Increased human health risks from air pollution, diminished water quality, and heat stress such as exacerbated asthma or increased water-borne illnesses.
- Changing pest, weed, and disease management challenges for farmers and livestock producers.
- Increased demand for energy, particularly during warmer summer months, meaning higher energy costs for consumers and increased strain on the grid to provide reliable power.
- More frequent flooding and associated disruptions due to sea level rise in communities and cities in the Delaware River Basin, including the city of Philadelphia.
- Potential for wetland drying in the Ridge and Valley ecoregion, resulting in loss of habitat for multiple wetland-dependent species, including many birds, frogs, salamanders, fish and fur-bearing mammals.
- Changing conditions for plant and animal species, with economic impacts to the timber industry, hunting, and fishing industries, and ecotourism.
- Changes in rainfall, snowfall, heat, and other conditions that will affect outdoor recreation, transportation, and general use of the outdoors.
- Potential for degraded water quality in the tidal freshwater portion of the Delaware estuary.

The impacts included in this report draw from the *Pennsylvania Climate Impacts Assessment* (Shortle et al. 2015). The assessment is updated every three years and provides scientific projections of changes in temperature and precipitation in Pennsylvania and the potential impacts in the commonwealth. Additional details on expected climate change impacts can be found in the latest assessment update.

These impacts could alter the many fundamental—but often not explicit—assumptions about climate that are intrinsic to the commonwealth's infrastructure, governments, and businesses. For example, bridges are designed for certain flooding return intervals, energy systems are designed for certain temperature ranges, farmers plant crops suited to historical climate conditions, ski mountain operators count on specific snow-making conditions, and communities are planned around historical floodplains. If not properly accounted for, changes in climate could result in more frequent road washouts, higher likelihood of power outages, shifts in economic activity, among other impacts. It is estimated that events such as these have cost governments (leaders), citizens, and businesses in the United States more than $1.1 trillion since 1980 (USGCRP 2017). Looking forward, annual losses in some sectors across the U.S. are projected to reach hundreds of billions by the end of the century (USGCRP 2018).

Climate change can also affect vital determinants of health such as clean air, safe drinking water, sufficient food as well as secure shelter. This can include impacts from increased extreme weather events such as heat, droughts, and floods, wildfire, decreased air quality, and illnesses transmitted by food, water, and disease carriers such as mosquitoes (USGCRP). Climate change is expected to cause around 250,000 additional deaths globally per year between 2030 and 2050 (WHO 2018). This includes deaths from malnutrition, malaria, diarrhea, and heat stress. There are additional direct damage costs to health from climate change, which is estimated to be around $2-4 billion per year by 2030 (WHO 2018).

Therefore, it is critical that leaders, citizens, and businesses in the Commonwealth of Pennsylvania:

- Consider how the commonwealth's climate may change in the future,
- Understand what (if any) impacts would occur if those changes are not addressed, and

- Take action to adapt to the changes and reduce the emissions that are causing them, while making the economy stronger.

The Commonwealth of Pennsylvania's government has already been leading on climate action through a series of work and activities. **The Pennsylvania Climate Change Act (Act 70 of 2008)** requires the Department of Environmental Protection (DEP) to develop an inventory of greenhouse gases (GHG) and administer a Climate Change Advisory Committee (CCAC), a voluntary registry of GHG emissions, and a Climate Change Action Plan. Revisions to the Action Plan are required every three years. (PA General Assembly 2008). In addition to this Act, other actions the Commonwealth of Pennsylvania has or is taking include:

- **Executive Action**
    - **Executive Order 2019-1** On January 8, 2019, Governor Wolf signed Executive Order 2019-1 "Commonwealth Leadership in Addressing Climate Change and Promoting Energy Conservation and Sustainable Governance." This Executive Order establishes climate goals for the Commonwealth of Pennsylvania for a 26 percent reduction of net greenhouse gas emissions statewide by 2025 from 2005 levels, and an 80 percent reduction of net greenhouse gas emissions by 2050 from 2005 levels. Additionally, the Executive Order sets energy performance goals for state agencies and creates a "GreenGov Council" to help agencies reach those goals.
- **Legislative Action**
    - **The Alternative Energy Portfolio Standard (AEPS) (Act 213 2004)** requires that 18 percent of electricity supplied by Pennsylvania electric distribution companies be generated by alternative energy sources by 2021. Alternative Energy Credits (AECs) can be used for compliance. Electricity generated in state or AECs can qualify as Tier 1 or Tier 2 sources: Tier 1 sources must comprise 8 percent of generation and may include solar, wind, low-impact hydro, geothermal, biomass, biologically derived methane gas, coal-mine methane and fuel cell resources; Tier 2 sources must comprise 10 percent of generation and may include waste coal, distributed generation (DG), demand-side management, large-scale hydro, municipal solid waste, wood pulping and manufacturing byproducts, and integrated gasification combined cycle (IGCC) coal (PA PUC 2018).
    - **Act 40 of 2017** prohibits in-state utility companies from using solar renewable energy credits from out-of-state projects to fulfill solar energy source requirements (PA General Assembly 2017).
    - **Pennsylvania Commercial Property Assessed Clean Energy (C-PACE) (Act 30 of 2018)** approves a financing mechanism that enables low-cost, long-term funding for energy efficiency upgrades to commercial and industrial properties, including renewable energy projects and installation of high efficiency heating, ventilation, and air-conditioning (HVAC) systems. The C-PACE program is expected to support the creation of new clean energy projects, enhance property values, and lower business costs by reducing the up-front costs of installing energy-efficient projects (Governor Tom Wolf 2018).

- **Act 36 of 2017** required the Review and Advisory Council (RAC) to re-review the 2015 ICC code. The RAC provided a report to Labor & Industry's Secretary on May 1, 2018 approving adoption of the 2015 ICC Code. Labor & Industry then promulgated regulations based on that report and they went into effect on October 1, 2018 (UCC RAC 2018).
- **Pennsylvania's Energy Efficiency and Conservation Law (Act 129 of 2008)** requires the commonwealth's major electric distribution companies to develop energy efficiency and conservation plans and adopt other methods of reducing the amount of electricity consumed by customers over three phases by implementing programs such as incentives for high-efficiency appliances, efficient new buildings, and industrial process upgrades. Efficiency and conservation programs must be cost-effective over fifteen years and savings are verified by third parties (PA PUC and PA PUC 2017).

- **Planning, Research, and Information Gathering**
  - **The Pennsylvania Department of Environmental Protection**
    - Previous versions of the Pennsylvania Climate Action Plan provide analysis and recommendations with the goal of finding cost-effective measures to reduce GHG emissions to mitigate climate change impacts in line with Act 70 requirements (see above). Since 2009, the Climate Action Plan has been updated every three years.
    - The *Pennsylvania Climate Impacts Assessment Update* was also prepared in response to Act 70, and requires the DEP to conduct a study of the potential impacts of global climate change on Pennsylvania over the next century. Three versions of this report have been released to date (Shortle et al. 2015).
    - DEP released the *Pennsylvania Electric Vehicle Roadmap*, recommending 13 strategies to increase use of these zero-emission vehicles. Partners such as the Drive Electric PA Coalition (DEPA) is working on ways to accelerate EV adoption in PA to state, municipal, private business fleets, as well as, individual purchasers of EVs (PA DEP 2018a).
    - The *Finding Pennsylvania's Solar Future Plan* brought together expert stakeholders from across sectors to explore whether Pennsylvania has sufficient photovoltaic potential to increase in-state solar generation to provide 10 percent of in-state electricity consumption by 2030. Stakeholders explored likely pathways to achieving that target and used modeling to identify associated economic, environmental, and health impacts. (PA DEP 2018b).
    - In Pennsylvania, multiple State Energy Planning/Marketing planning efforts are underway. For 2018-19, DEP will synthesize the work that has been done into one cohesive, strategic energy plan.
  - **The Pennsylvania Department of Conservation and Natural Resources (DCNR)** has led multiple climate initiatives including developing a *Climate Change Adaptation and Mitigation Plan* in 2018, outlining 123 action steps to be undertaken to make the state more resilient to potential climate change impacts. The DCNR has also reported other climate

change issues such as the 2015 report, *Planning for the Future,* in addition to conservation activities though the long-standing Wild Resource Conservation Program.

- **The Pennsylvania Department of Community and Economic Development (DCED)** manages financing programs for grants and loans for clean and alternative energy projects including buildings, equipment and land development activities; grants and loans to individuals and small businesses for high-performance, energy-efficient building projects; grants and loans for geothermal and wind energy projects; and grants and loans for alternative energy production projects involving solar technologies as enacted by the Alternate Energy Investment Act of July 2008.

- **Program Implementation**

  - **The Alternative Fuels Incentive Grant (AFIG) Program (Act 166 of 1992)** aims to create new markets for alternative fuels, fleets, and technologies to enhance the state's energy security with the objectives of improving the environment, supporting economic development, and enhancing quality of life (PA DEP 2018c).

  - **The Natural Gas Energy Development Program (Act 13 of 2011)** aims to increase the use of domestically produced natural gas resources through impact fee provisions, upgraded environmental regulations, and local ordinance preemption and restrictions. Broadly, the program imposes new environmental obligations of natural gas producers, but also promotes natural gas production while raising revenue through the impact fees (PA General Assembly 2012).

  - **Other Programs, include:**

    - **Regional Pooled Municipal Energy Implementation Program.** The Delaware Valley Regional Planning Commission (DVRPC) plans to build off of their existing successful Regional Streetlight Procurement Plan for the implementation of more rounds with interested municipalities as a model to develop a best practices step-by-step report for other regions interested in executing a regional pooled energy implementation program.

    - **Wastewater Treatment Plant (WWTP) Operators Energy Outreach.** According to the United States Department of Energy's (DOE's) WWTP Energy Data Management Manual, electricity alone can constitute 25% to 40% of a wastewater treatment plant's annual operating budget. A series of training events will be provided for 50-80 operators of smaller to mid-sized municipally owned WWTP.

    - **Energy Assurance Activities.** DEP has recently updated the Energy Assurance Plan which includes a Petroleum Shortage Response Plan. As a critical next step in ensuring resiliency efforts, DEP and the Pennsylvania Emergency Management Agency (PEMA) are educating local governments on planning and responding to energy emergencies from disasters.

    - **Building Operator Certification (BOC).** The BOC program on average saves roughly 100,500 kWh of electricity per certified operator per year. This represents a savings

of $10,500 annually for a 5-year period. DEP is contracting with the Pennsylvania College of Technology's National Sustainable Structures Center to provide BOC Level 1 trainings to PA facility managers and HVAC mechanics/technicians from K-12 schools, higher education, and government agencies.

- **Building Retuning Training (BRT).** DEP is contracting with the Pennsylvania Technical Assistance Program (PennTAP) to provide BRT walkthroughs of facilities and workshops that include obstacles to implementation for local governments and schools in Southwestern PA.
- **Energy Codes Training.** DEP is contracting with the Pennsylvania Municipal League to offer 2015 International Energy Conservation Code (IECC) trainings by the sub-contractor Performance Systems Development to code officials, builders, design professionals and third-party inspectors.
- **Energy Efficiency (EE) Assessments for Small to Mid-Sized Manufacturers/Agricultural Sector.** PennTAP and Emerging Technology Applications Center are contracted to provide EE assessments and technical assistance for small to mid-sized manufacturers.
- **DEP Outreach to Schools.** DEP staff members have been participating in the PA Green & Healthy Schools Partnership (PAGHSP) for several years, a collaboration of government agencies, nonprofits, K-12 schools, higher education institutions, and individuals who are committed to promoting healthy schools within the commonwealth. The PAGHSP plans to organize and implement several workshops over the course of the next year focusing on Eco-Schools USA, a framework for engaging students in school environmental initiatives, including energy.
- **Pennsylvania Energy Development Authority (PEDA) Grant Program.** PEDA's mission is to finance clean, advanced energy projects in Pennsylvania. No new funding is proposed at this time. DEP staff continue to manage existing grants and provide administrative support to the program.
- **Green Energy Loan Fund.** DEP staff oversee the grant with Reinvestment Fund which administers the Pennsylvania Green Energy Loan Fund for large building energy efficiency retrofits.
- **TreeVitalize Grant Program.** DCNR administers the TreeVitalize grant program that provides funding support and tree tender training to communities that want to add urban tree canopy to their towns and cities. Program announcements and guidelines are issued through DCNR's website on an annual basis.

Pennsylvania's Energy and GHG Emissions

The Importance of Energy in Pennsylvania

Since the start of the commercial petroleum industry in the 1850s, Pennsylvania has been a leader in energy markets. Pennsylvania is rich in natural fossil resources, starting with coal in the 18th century, oil in the 19th century, and focusing on natural gas in the 21st century. In addition to its wealth of carbon-based fuels, Pennsylvania's energy landscape now features renewables and other alternative energy resources. Advances in renewable technologies and policy and program initiatives are allowing these low-carbon energy sources to play increasingly pivotal roles in Pennsylvania's energy story.

Because of its strong resource base, Pennsylvania is consistently one of the top energy-producing states in the United States and is one of the country's leading electricity exporters. This results in many economic benefits for the commonwealth (e.g., clean energy is a large economic driver for Pennsylvania–all 67 counties have residents working on clean energy and Pennsylvania ranks 11th among all 50 states and Washington D.C. in clean energy jobs (energy efficiency, renewable energy, energy storage, and clean vehicles) (E2 2018), but also comes with the serious responsibility of understanding and mitigating the associated risks and effects (e.g., 88 percent of 2015 GHG emissions, in Pennsylvania come from energy production and consumption). For more information on Pennsylvania's energy picture, refer to the DEP *Energy Assessment Report for the Commonwealth of Pennsylvania*. This report characterizes current, future, and potential energy trajectories in Pennsylvania, providing readers with an overview of the commonwealth's energy picture and the potential opportunities for future energy development. It includes both a business-as-usual energy assessment through 2050 and an assessment of energy resource potential opportunities through 2050. The analyses presented in this Plan are generally consistent with the information presented in the *Energy Assessment Report for the Commonwealth of Pennsylvania.*[2]

Pennsylvania's GHG Emissions Modeling

As required by the Pennsylvania Climate Act, DEP must prepare a greenhouse gas emissions inventory annually. This GHG inventory serves as the basis for the statewide reductions called for in Governor Wolf's Executive Order 2019-1 "Commonwealth Leadership in Addressing Climate Change and Promoting Energy Conservation and Sustainable Governance." DEP prepares the statewide GHG inventory using the U.S. Environmental Protection Agency's (EPA) State Inventory Tool (SIT). Because EPA's SIT is produced each year, and the methods of calculating emissions are refined with each version, estimates of previous years can often change slightly.

[2] The "business as usual" (BAU) scenario in this analysis differs from the data presented in *Energy Assessment Report for the Commonwealth of Pennsylvania*. BAU electricity generation from traditional nuclear in the Energy Assessment report anticipates the potential closure of Three Mile Island; the closure of Beaver Valley Nuclear Power Station was announced after the Energy Assessment was completed but has been included in the BAU for the Climate Action Plan analysis.

The SIT, and DEP's GHG inventory, is a generation-based model of accounting for emissions. The generation model accounts for emissions based on the amount of electricity generated by various fuels in Pennsylvania, regardless of whether that electricity is consumed in Pennsylvania or exported to other states. It is worth noting that the electricity that is produced in Pennsylvania and exported to other states, reduces emissions in those importing states because the electricity is not being generated there.

DEP's Inventory includes emissions from the residential, commercial, industrial, transportation, electricity production, agriculture, waste management, forestry, and land use sectors. DEP produces this inventory annually, which helps to track emissions trends over time, gauge progress on the commonwealth's emissions reduction goals, and refine the baseline that those goals are measured against.

In 2015, the most recent inventory available, total statewide emissions in Pennsylvania were 287 $MMTCO_2e$ while net emissions (accounting for emissions sinks from forestry and land use) were 257 $MMTCO_2e$. These emissions have been reduced since 2005, when total statewide emissions were 326 $MMTCO_2e$ and net emissions were 291 $MMTCO_2e$. Recent emissions reductions have occurred primarily due to a shift in the electricity portfolio mix and energy efficiency measures. Since 2005, Pennsylvania's electricity generation has shifted from higher carbon-emitting electricity generation sources, such as coal, to lower and zero emissions generation sources, such as natural gas, wind and solar energy. At the same time, overall energy use in the residential, commercial, transportation, and electric power sectors has been reduced.

	2005 actual	**2015 actual**	**2025 target**	**2050 target**
Net Emissions (MMTCO2e)	291	257	215	58
Difference (MMTCO2e)		34	76	233
Percent Change		12%	26%	80%

It is important to note that the modeling included in this Climate Action Plan does not account for emissions in this exact way, therefore the emissions estimates in this Plan are not directly comparable to the estimates in DEP's annual GHG inventory.

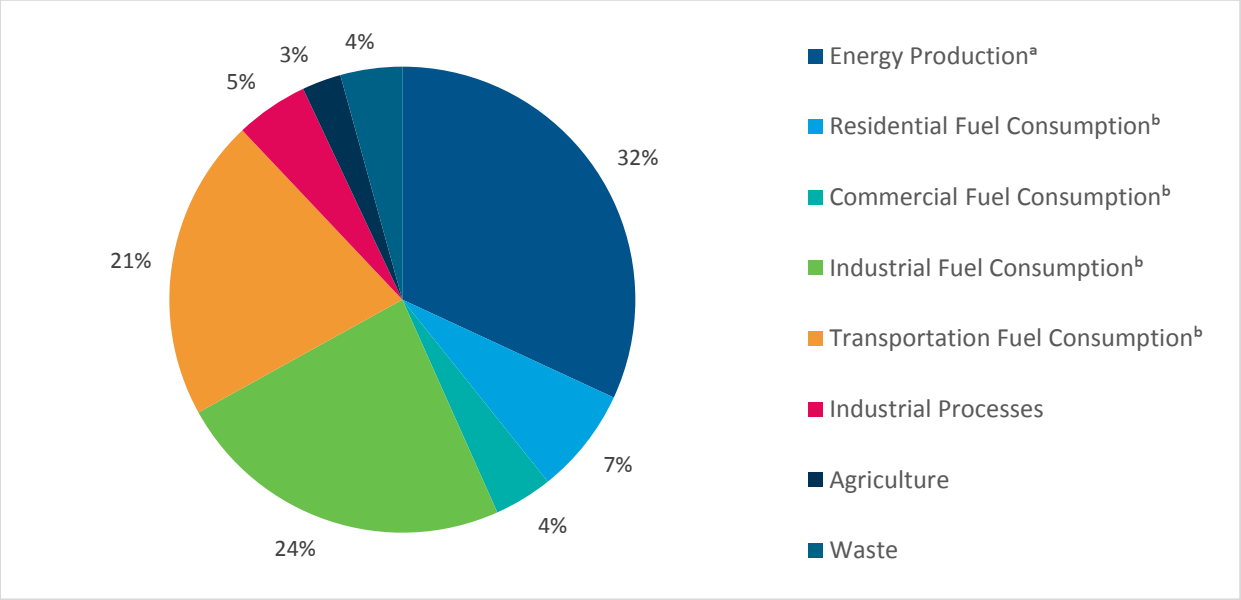
For the purposes of conducting modeling analysis in this Plan, the analysis team accounted for emissions using a consumption-based model. This method of calculating GHG emissions in this manner is to account for emissions associated with only the electricity used within the commonwealth and not the electricity exported. This approach is applied as a direct assessment of the effectiveness of the recommended strategies in this Plan and allows emissions within Pennsylvania's borders to be fully captured. The effectiveness of the policies and programs that address both electricity use (e.g., Act 129) and generation (e.g., the AEPS) is predicted. The consumption model considers any changes in GHG emissions a result of both:

- Changes in end use electricity consumption; and

- Changes in the mix of fuels used to generate electricity, which is accounted for by using an electricity grid emission factor that varies over time.

The remainder of this Plan, including all emissions estimates for past and future years, is based on the consumption model of GHG emission accounting. Using this method of calculation, the analysis team assessed recent trends and the breakdown of emissions by sector. Figure 5 shows contributions from each sector to overall GHG emissions in 2015 in Pennsylvania based on this consumption model.

Figure 5. Proportion of 2015 GHG Emissions (Excluding Sinks) by Sector



[a] Energy Production includes emissions from electricity generation, coal mining, and natural gas and oil production.
[b] Fuel Consumption includes emissions from direct fuel consumption. It does not included emissions from electricity consumption.

Pennsylvania's Future GHG Emissions without Additional Action

The benefits and costs of these 15 emissions reduction actions identified are measured relative to 2005 base year GHG emission levels to assess target achievement and further compared to a business as usual (BAU) scenario in which emissions are projected through 2050 to show the GHG benefits over time. 2015 is the most recent year for which a complete set of data is available for historical emissions. Therefore, GHG emissions are projected for 2016-2050 using a combination of the Energy Information Administration's (EIA) Annual Energy Outlook, SIT projections, and other supporting data sources.

In the BAU scenario, depicted in Figure 6, total and net emissions (including emissions sinks) are expected to increase by 4 percent and 5 percent, respectively, from 2015 to 2050. Net emissions (including sinks) are used for setting and tracking GHG reductions over time and assessing achievement of GHG targets.

Figure 6. BAU GHG Emissions ($MMTCO_2e$)

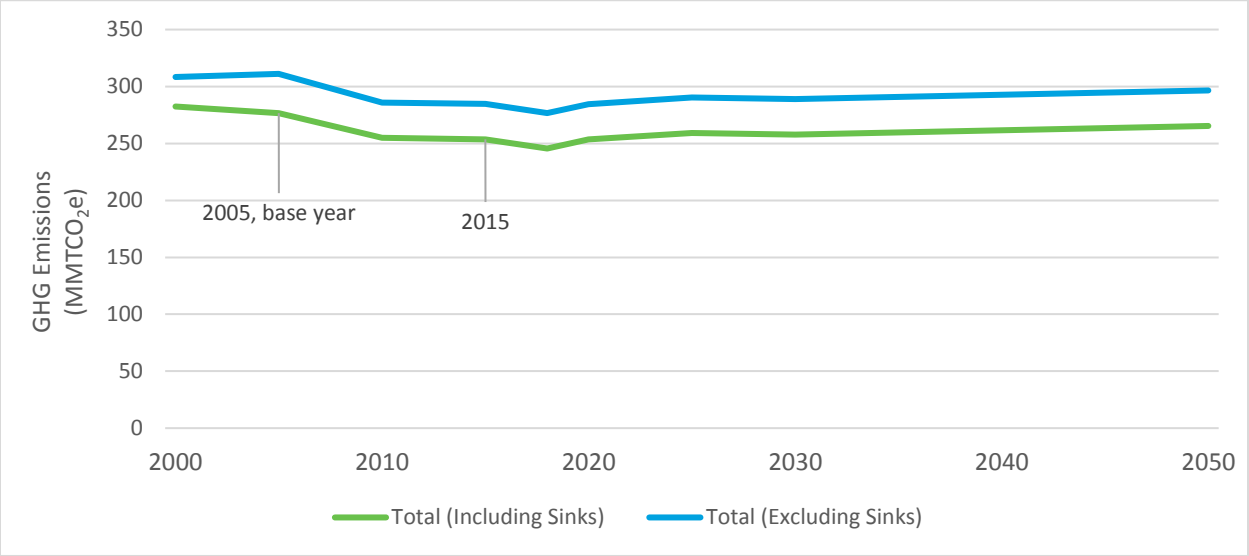


Figure 7 and Table 1 show the contribution of each sector to total GHG emissions in the BAU scenario through 2050 (leaving out emissions sinks). Overall energy sector emissions are expected to increase by about 5 percent from 2015 to 2050. Emissions from energy consumption are expected to increase by 4 percent from 2015 through 2050, with emissions from transportation sector electricity consumption expected to increase by four times as electric vehicle adoption grows across Pennsylvania. Emissions from energy production (e.g., fugitive emissions from coal mining and natural gas and oil production) are expected to grow 8 percent from 2015 to 2050.

Industrial sector electricity consumption emissions are also expected to increase significantly from 2015 to 2050, rising by 26 percent in the BAU scenario. Emissions from the agriculture sector are projected to decrease 5 percent while waste sector emissions increase by 12 percent. The amount of carbon sequestered by the land use and forestry sector are projected to remain relatively constant from 2015 to 2050.

Figure 7. BAU GHG Emissions (Excluding Sinks) by End-Use Sector ($MMTCO_2e$)

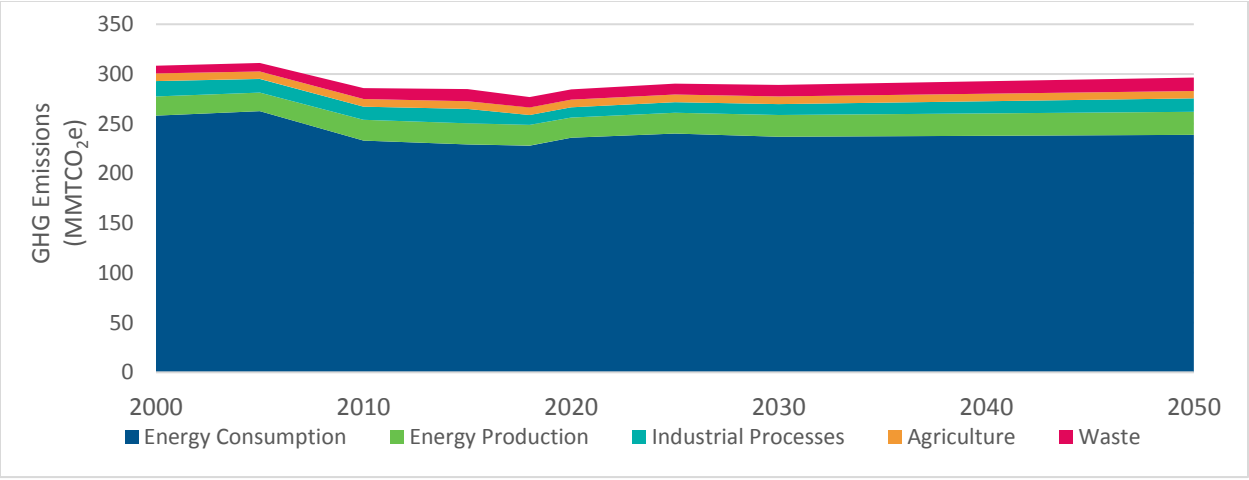


Table 1. BAU GHG Emissions by End-Use Sector ($MMTCO_2e$)

Sector	2000	2005	2015	2025	2030	2050
Energy Consumption	258	263	229	240	237	239
Energy Production	19	19	21	21	22	23
Industrial Processes	15	14	14	11	11	14
Agriculture	8	8	8	8	8	7
Waste	8	9	12	11	12	14
Total Emissions	308	311	285	290	289	296
Emissions Sinks	-26	-34	-31	-31	-31	-31
Net Emissions	282	277	254	259	258	265

Note: Totals may not sum due to independent rounding

Climate Action Plan Organization

The remainder of this Plan includes:

- **Section 2: What's Included In this Plan,** describes overarching goals of the Plan, methods used to develop the Plan and its contents, and the sectors, strategies, and actions covered by the Plan.
- **Section 3: Pennsylvania's Climate Impacts, Emission Reduction, and Adaptation Opportunities** presents a list of potential strategies and actions leaders, citizens, and business in Pennsylvania can take to address and adapt to climate change. Where feasible, modeled and qualitative impacts of each strategy are presented.
- **Section 4: Benefits and Costs for Modeled Strategies and Actions** provides a summary of quantitative impacts and GHG reductions and micro- and macro-economic modeling results by strategy and action.

2 What's Included in this Plan?

Adaptation Goals and Emission Reduction Targets

This 2018 Climate Action Plan Update comprehensively considers the changing climate in Pennsylvania by addressing both the impacts of climate change ("adaptation") and the causes of climate change (reducing greenhouse gas emissions, or "mitigation"). To ensure the effectiveness of this Plan, overarching adaptation goals and GHG emissions reduction targets are used to frame the strategies. In addition to the goals and targets outlined below, and per Act 70 of 2008, cost-effectiveness is also a key factor for strategy selection.

Helping Pennsylvanians Adapt to the Impacts of Climate Change

This Plan identifies two adaptation-focused goals, which can be achieved by actions from leaders (government), citizens, and businesses in the commonwealth:

- Minimize disruptions to Pennsylvania's citizens, economy, and environment from climate-related hazards.
- Increase Pennsylvania's ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from climate-related disruptions.

Driving Ambitious Action to Reduce Pennsylvania's GHG Emissions

To ensure its contributions to human-caused climate change are not irreversible, all Pennsylvanians (citizens, businesses, and leaders) must understand how they can help keep global temperature increases below 2 degrees Celsius. This threshold for global temperature rise is cited by experts as the level beyond which dire consequences would occur, including sea level rise, superstorms, and crippling heat waves (IPCC 2014). It's been projected that United States GHG emissions would need to be reduced 26-28% by 2025 and 80% by 2050 to ensure global temperatures stay below that level (UNFCCC 2015).

It is partly for these reasons that in January 2019, Governor Wolf signed Executive Order 2019-01 "Commonwealth Leadership in Addressing Climate Change and Promoting Energy Conservation and Sustainable Governance" which states that Pennsylvania shall strive to reduce net greenhouse gas emissions 26 percent by 2025 from 2005 levels, and 80 percent by 2050 from 2005 levels, among other initiatives and goals. Governor Wolf's leadership, initiatives, and focus on climate change, which he calls the most critical environmental threat confronting the world, is fully consistent with the goals and targets in this Plan. These targets are also in line with GHG reduction targets set by many other countries and states.[3]

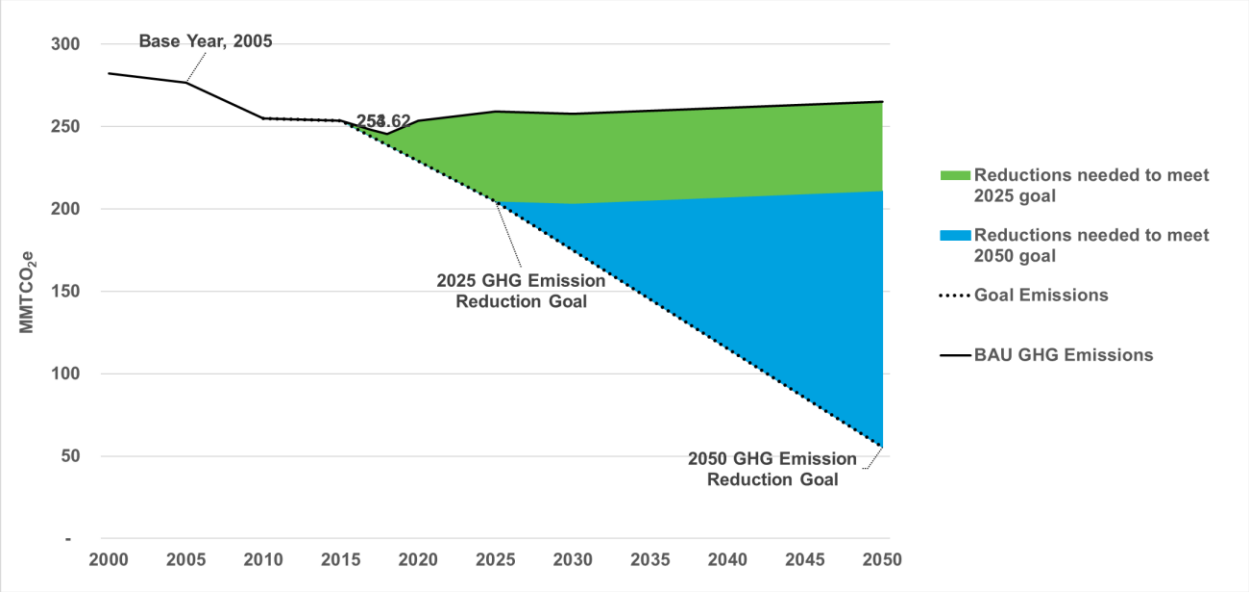
[3] For example, the U.S. Climate Alliance, which includes 16 states, set the same GHG reduction target for 2025. Additionally, the Under2 Coalition promotes a guiding principle that their parties pursue emission reductions consistent with a trajectory of 80 to 95 percent below 1990 levels, which is in line with 80 percent reduction of 2005 levels. By this standard, an 80 percent reduction by 2050 target that uses 1990 as a base year could be considered science-based. Aligning the targets within the 2018 CAP to targets set by other states helps to ensure that any target selected is achievable and that the corresponding GHG reduction strategies remain viable and cost effective.

If all states achieved such targets, and other nations met comparable goals, climate science analysis suggests that global temperature rise could be kept below the 2-degree Celsius threshold. Accordingly, the GHG reduction targets used in this Plan are:

- 26 percent reduction of net GHG emissions by 2025, from 2005 levels.
- 80 percent reduction of net GHG emissions by 2050, from 2005 levels.[4]

In the BAU scenario, net annual GHG emissions in Pennsylvania were 277 $MMtCO_2e$ in 2005. Net annual GHG reductions of 26 percent in 2025 would result in 205 $MMtCO_2e$, and an 80 percent reduction would yield 55 $MMtCO_2e$. These targets are illustrated in Figure 8.

Figure 8. BAU Net GHG Emissions and GHG Reductions Required to Meet Modeling Targets ($MMTCO_2e$)



How this Plan was Developed

The strategies in this report reflect an iterative process between the DEP Energy Programs Office (EPO), Bureau of Air Quality (BAQ), and Policy Office and their sister agencies (DCNR, the Pennsylvania Departments of Agriculture, Community and Economic Development, Health, Transportation, General Services, the Pennsylvania Emergency Management Agency, and Pennsylvania Public Utility Commission), the Climate Change Advisory Committee (CCAC) and other stakeholders.

1. DEP and the supporting analysis team (ICF) started by separately identifying strategies with adaptation benefits and strategies with emissions reduction benefits. The team then iteratively prioritized and integrated the strategies, prioritizing those with both adaptation and emissions reductions benefits.

[4] This Action Plan analyzes the targets on a consumption-based model to determine the amount of greenhouse gas emissions reduced from mitigation strategies. The target set by Executive Order 2019-1 is established for reductions to all greenhouse gases emissions generated in Pennsylvania, including those from energy that is exported to other states.

- To identify strategies with adaptation benefits, DEP and the analysis team developed an extensive list of adaptation-focused policies, programs, and actions based on a literature review of numerous sources. The team then consolidated the actions and refined strategies based on feedback from Pennsylvania agencies, evaluation against criteria (e.g., impacts addressed, emissions co-benefits, early-action characteristics), and opportunities to eliminate redundancies.
- To identify strategies with emissions reduction benefits, the team compiled a list of strategies from previous Pennsylvania CAPs, DEP and CCAC suggestions, strategies identified by other jurisdictions, and a comprehensive review of energy resource potential in Pennsylvania.

2. DEP and the team then refined the list based on internal DEP and CCAC feedback, and worked with them to select strategies to quantitatively model to estimate GHG reductions, cost-effectiveness, and other effects. Strategies were selected for modeling based on an initial screen of potential contributions to GHG reductions—strategies that were expected to result in larger GHG reductions were quantitatively assessed. Most of the strategies focused on clean energy, in line with the fact that the vast majority of emissions (88 percent in 2015) in Pennsylvania come from energy production and consumption.
3. DEP and the analysis team then conducted modeling for selected strategies for GHG, energy, and micro-economic effects. The modeling process was iterative, with the analysis team seeking feedback and input from DEP and the CCAC at certain points throughout the process to ensure their assumptions and inputs were captured. This Plan provides a high-level summary of the methods used for quantitative modeling in respective strategy sections. More detailed information on modeling assumptions, methods, data, and results for GHG emissions, energy, criteria air pollutant emissions, and micro-economic impacts can be found in Appendix A, and below in the description of benefits and costs for each strategy.
4. Macro-economic modeling (e.g., changes in jobs) was conducted using the REMI PI+ model. This is a structural economic forecasting and policy analysis model that integrates several analytic techniques including input-output, computable general equilibrium (CGE), econometric, and economic geography methodologies. REMI is a dynamic model, with forecasts and simulations to include behavioral responses to wage, price, and other economic factors. It can be used for estimating national, regional, and state-level impacts of any policy changes. The dynamic modeling framework supports the option to forecast how changes in the economy, and adjustments to those changes, will occur on an annual basis.
    - REMI functions by forecasting two states of the world. The first is the state of the regional economy under some standard assumptions of employment and population changes. This first forecast is referred to as the control forecast. The second forecast, in which the model user incorporates the desired policy changes, is referred to as the alternative forecast or the simulation. The difference between the two forecasts would be the estimated effect of the policy. Policy changes that were input into REMI were modeled by the analysis team as described above.
5. Lastly, DEP and the analysis team outlined additional specific actions within each strategy for leaders, citizens, and businesses and specified implementation steps for modeled actions.

Plan Sectors, Strategies, and Actions

This report is first organized by sector. Within each sector, multiple strategies are outlined. The term "strategy" encompasses multiple actions—specific policies, programs, or activities for state and local leaders, citizens, and businesses.

Sectors

This Plan is organized by sectors, including:

- Energy Consumption
- Energy Production
- Agriculture
- Ecosystems & Forestry
- Outdoor Recreation & Tourism
- Waste Management
- Water Resources
- Human Health

Strategies

The strategies presented in this Plan include actions that can reduce GHG emissions, increase energy efficiency and adoption of clean energy practices and technologies, address existing vulnerabilities, avoid creation of future vulnerabilities, and build Pennsylvania's capacity to adapt to climate change over time. Many of these strategies may entail significant costs, but all are projected to provide sizeable benefits in the long run, as Pennsylvania's governments, businesses, and citizens work to ensure that the commonwealth continues to thrive over the coming century. While some strategies focus narrowly on specific sectors, many have actions, benefits, costs, and climate impacts that cut across sectors Table 2 below summarizes where to find each strategy within the report, as well as other sectors related to the strategy. It also indicates which strategies include actions with quantified benefits and costs and if the strategy addresses climate mitigation, adaptation, or both.

Table 2: Summary of Strategies

	Energy Consumption	Energy Production	Agriculture	Ecosystems & Forestry	Outdoor Rec & Tourism	Waste Management	Water Resources	Human Health	Includes Modeled Actions	Reduces GHG Emissions	Increases Ability to Adapt
Increase end use energy conservation and efficiency	✱		●			●	●	●	✓	✓	✓
Implement sustainable transportation planning and practices	✱			●				●	✓	✓	✓
Develop, promote, and use financing options to encourage energy efficiency	✱		●			●	●	●		✓	✓
Increase use of clean, distributed electricity generation resources		✱	●			●	●	●	✓	✓	✓
Create a diverse portfolio of clean, utility-scale electricity generation		✱	●			●	●	●	✓	✓	✓
Reduce impacts of fossil fuel energy production and distribution		✱		●		●	●	●	✓	✓	
Increase production and use of alternative fuels		✱	●			●		●	✓	✓	✓
Use agricultural best practices	●		✱	●		●	●	●	✓	✓	✓
Provide resources and technical assistance to farmers to adapt			✱	●			●	●			✓
Protect ecosystem resilience, including forest systems where species will shift				✱	●		●	●		✓	✓
Monitor, identify, and address ecosystem vulnerabilities				✱	●			●			✓
Help the outdoor tourism industry manage shifting climate patterns				●	✱		●	●			✓
Reduce waste generated by citizens and business thereby reducing waste sent to landfills, and WTE facilities, and expand the beneficial use of waste		●	●			✱		●		✓	✓
Use stormwater best management practices	●						✱	●		✓	✓
Promote integrated water resources management and water conservation	●						✱	●			✓
Improve reliability and accessibility of public information about climate-related health risks								✱			✓
Bolster emergency preparedness and response								✱			✓
Lead by example in commonwealth and local government practices and assets	●	●	●	●	●	●	●	●		✓	✓
Incorporate historical and projected climate conditions into siting and design decisions for long-term infrastructure	●	●	●	●	●	●	●	●			✓

✱ strategy presented in this sector ● strategy relates to this sector

Actions

Actions include various policies, programs, or activities that leaders (state and local government), citizens, and businesses can take to reduce GHG emissions and adapt to climate change impacts. Within each strategy, the Plan outlines a list of specific actions that each stakeholder group can take. Of the many actions listed, the analysis team quantitatively analyzed 15 of the actions that leaders could take, as shown in Table 3. Table 4 identifies additional actions the analysis team qualitatively analyzed, which would provide additional benefit to the commonwealth.

Table 3. Emissions Reduction Actions for Leaders Modeled for the 2018 PA Climate Action Plan (CAP) Update, Organized by Sector and Strategy

Sectors	Strategies	Actions Included in Quantitative Modeling	GHG Emission Reductions in 2025 ($MtCO_2e$)	GHG Emission Reductions in 2050 ($MtCO_2e$)
Energy Consumption	Increase end use energy conservation and efficiency	• Update building codes	1,164,587	5,374,682
		• Increase adoption of energy efficiency, and expand Act 129	1,916,947	1,984,261
		• Create an Act 129-like conservation and efficiency program for natural gas	845,010	1,567,198
		• Expand energy assessments and provide more trainings on energy efficiency for industry	1,901,335	3,110,031
	Implement sustainable transportation planning and practices	• Reduce vehicle miles traveled for single-occupancy vehicles	573,260	2,820,936
		• Implement a strategic plan and incentives for increasing electric vehicle use	474,100	21,689,937
		• Increase the use of clean public transportation through electric municipal bus fleets	13,948	458,048
Energy Production	Increase use of clean, distributed electricity generation resources	• Invest in and promote building-scale solar	NA[a]	48,210
		• Incentivize and increase use of combined heat and power (CHP)	544,502	-1,561,128[b]
	Create a diverse portfolio of clean, utility-scale electricity generation	• Increase Alternative Energy Portfolio Standard (AEPS) Tier 1 targets, and further increase in-state generation and use of renewables	6,703,719	27,639,941
		• Implement policy to maintain nuclear generation at current levels	18,412,115	21,152,811
		• Limit carbon emissions through an electricity sector cap and trade program	4,899,227	NA[c]

Sectors	Strategies	Actions Included in Quantitative Modeling	GHG Emission Reductions in 2025 ($MtCO_2e$)	GHG Emission Reductions in 2050 ($MtCO_2e$)
	Reduce impacts of fossil fuel energy production and distribution	• Implement policies and practices to reduce methane emissions across oil and natural gas systems	104,879	29,598
	Increase production and use of alternative fuels	• Increase recovery and use of gas from coal mines, agriculture, wastewater, and landfills for energy	1,673,531	2,796,683
Agriculture	Use agricultural best practices	• Increase adoption rate of and provide training for no-till farming practices	208,331	328,070

[a] *There is sufficient building scale solar in 2025 in the BAU to meet the 6% solar carve out assuming 90% is utility scale and 10% is building scale, so there are no GHG reductions from BAU in 2025. We see non-zero savings starting in 2026.*

[b] *A negative value indicates an increase in GHG emissions.*

[c] *The GHG emission reductions from expanding AEPS requirements and maintaining nuclear generation are projected in this modeling analysis to meet the emissions reduction target in 2050 without additional reductions from a cap and trade program.*

To the extent feasible, interactions between some actions and strategies are captured in the modeling effort. Specifically:

- **Increase end use energy conservation and efficiency.** GHG emissions are reduced directly through changes in end use energy consumption from the energy efficiency actions identified in Table 3. The modeling for this strategy also factors in changes in electric generation carbon intensity from the strategy "create a diverse portfolio of clean, utility-scale electricity generation." Accordingly, GHG emissions estimates are a joint function of electricity usage reductions and carbon intensity per unit of consumption. Reductions in energy consumption from efficiency actions are also factored into other actions' impacts, both within the energy efficiency strategy and across strategies. For example, BAU electricity consumption used to estimate reductions from the "increase adoption of energy efficiency and expand Act 129" action is adjusted based on impacts estimated from the "update building codes" action. And such BAU electricity consumption adjustments are also applied to other power sector strategies, such as "Create a diverse portfolio of clean, utility-scale electricity generation."
- **Implement sustainable transportation planning and practices.** GHG emissions are reduced directly through reductions in vehicle miles traveled (VMT), electrification of passenger vehicle fleets, and adoption of zero emissions transit buses from the actions identified in Table 2. The modeling also factors in the change in electricity-sector carbon intensity over time from the "create a diverse portfolio of clean, utility-scale electricity generation" strategy, such that the emissions impacts of increased electricity usage from electric vehicles as adjusted accordingly. Also, the "implement a strategic plan and incentives for increasing electric vehicle use" action

factors in the reduced average VMT per vehicle resulting from the "reduce vehicle miles traveled for single-occupancy vehicles" action.

- **Increase use of clean, distributed electricity generation resources.** GHG emissions are reduced through the installation of distributed renewable energy sources. As emissions reductions are estimated based on the reduction in grid electricity consumption, the modeling conducted by the analysis team for this strategy also factors in the change in electricity carbon intensity over time as driven by the "create a diverse portfolio of clean, utility-scale electricity generation."
- **Create a diverse portfolio of clean, utility-scale electricity generation.** This Plan accounts for Scope 2 GHG emissions (or GHG emissions caused at the powerplant level by end-use electricity consumption), assuming all electricity consumption is sourced from generation in Pennsylvania. Therefore, a reduction in the carbon intensity of Pennsylvania's generation will result in a lower emission factor being applied to Scope 2 emissions from electricity consumption–these impact emissions for most all other strategies. In particular, it allows reductions from both lower carbon intensity of utility-generated electricity and reductions in end-use electricity consumption to contribute toward meeting the targets outlined in this Plan. As part of this strategy, the analysis team assumes that both the AEPS expansion and maintaining current levels of nuclear generation contribute to meeting the emission reductions target set by the power sector carbon cap and trade action. Remaining reductions needed to meet the cap and trade emissions reduction target are obtained through shifting dispatch of coal-fired generation to natural gas-fired generation.
- **Increase production and use of alternative fuels.** GHG emissions are reduced through changes in end use energy consumption due to increased use of alternative fuels resulting from the actions identified in Table 3. The modeling conducted by the analysis team for this strategy also factors in the change in electricity carbon intensity over time as driven by the "Create a diverse portfolio of clean, utility-scale electricity generation."

The actions in Table 3 represent only a subset of the potential actions, within a subset of the identified strategies. In other words, the benefits and costs quantified in this analysis do not comprehensively account for those that could accrue from the full set of strategies and actions identified in this Plan. If Pennsylvania leaders pursue actions and strategies beyond those that were quantitatively assessed (see Table 4), and if citizens and businesses committed to act accordingly, there would be additional benefits and costs from reducing GHG emissions and adapting to climate change.

Table 4. Emissions Reduction and Adaptation Actions for Leaders Qualitatively Assessed for the 2018 PA CAP Update, Organized by Sector and Strategy

Sectors	Strategies	Actions Qualitatively Assessed
Energy Consumption	Increase end use energy conservation and efficiency	• Expand home weatherization programs.
		• Increase support for market trends for energy efficient technologies.
		• Replace high carbon and GHG producing fuels or energy sources with less environmentally impactful options.
		• Educate consumers about the benefits of occupant performance and low energy usage improvements in building system technologies.
	Implement sustainable transportation planning and practices	• Develop people-mover systems, such as West Virginia University's Personal Rapid Transit system.
		• Continue and expand efforts to assess climate risks to transportation and land use planning, and incorporate expected future conditions into capital planning, project design, and routine operations, maintenance, and inspection practices.
		• Improve preparedness for increased frequency of extreme events by improving coordination between agencies and other stakeholders and by improving real-time monitoring of flooding, traffic, and other conditions.
		• Prioritize and provide guidance to local governments on transportation and land use planning that promotes efficient use of public resources, reduces congestion, and minimizes GHG emissions through multi-modal transportation networks and compact, transit-oriented development that uses smart growth practices and complete streets.
		• Educate citizens and business on the benefits of transportation demand-side management measures and clean and efficient transport options.
		• Increase adoption of people-powered transportation options such as walking school buses or commuter bicycle paths.
		• Reduce non-CO_2 emissions (hydrofluorocarbons) from truck and stationary refrigeration systems.
		• Participate in the Transportation Climate Initiative, and help develop and implement regional market-based policies that would both reduce carbon pollution from the transportation sector and fund clean transportation investments.
	Develop, promote, and use financing options to encourage energy efficiency	• Expand use of performance contracting.
		• Create state and local clean energy tax incentives.
		• Establish/expand residential energy efficiency loan programs similar to Keystone HELP.
		• Evaluate options for and engage in public-private partnerships (P3), and capitalize on them.
		• Encourage utilities to provide on-bill financing or repayment.
		• Fund a green bank through new revenue streams (e.g., energy efficiency charges on utility bills in Vermont).
		• Encourage broad implementation of recent commercial PACE legislation.
		• Explore residential PACE once consumer protections are in place.

Sectors	Strategies	Actions Qualitatively Assessed
Energy Production	Increase use of clean, distributed electricity generation resources	• Support community solar legislation and develop model local ordinances (e.g., to streamline community solar development).
	Create a diverse portfolio of clean, utility-scale electricity generation	• Establish a workgroup to help optimize siting of renewables, and to review and streamline permitting and regulations at the state and local levels. Focus on high value, implementable actions such as community choice aggregation and battery storage.
		• Establish a CO_2 emissions fee for power generators as part of a carbon tax or other GHG pricing policy action.
	Increase production and use of alternative fuels	• Increase sustainable biofuel production in Pennsylvania (e.g., expand on biodiesel requirements).
		• Finalize the draft Bureau of Air Quality general permit for reciprocating engines using LFG, which incentivizes increased beneficial use of landfill gas, and reduces downtime due to maintenance at existing projects.
		• Continue to support the sustainable harvest and use of biomass feedstocks for thermal energy through initiatives such as PA Fuels for Schools and Communities
Agriculture	Use agricultural best practices	• Expand integrated farm management and conservation planning
		• Expand regional planning initiatives, especially in agricultural areas, focusing on agricultural security zones and local food security
		• Revise/update existing conservation and agricultural measures to see how they could further support resilience to climate change, and modify where necessary
		• Provide financial incentives and support for agricultural best practices.
	Provide resources and technical assistance to farmers to adapt	• Establish a network of agro-meteorological stations statewide to collect climate observations, including estimates of evapotranspiration, to support research and development of agricultural practices.
		• Expand the collection and dissemination of local weather information for irrigation planning.
		• Improve the accuracy of existing real-time weather warning and forecasting systems for drought and extreme events.
		• Develop and disseminate seasonal climate forecasts.
		• Conduct or sponsor research to understand topics such as climate change effects on weeds, insects, and diseases; best practices for agricultural emergency response plans; conservation best practices; and methods for maintaining the genetic diversity of crops.
		• Facilitate information sharing networks for farmers and the agricultural research community to share experiences and best practices.

Sectors	Strategies	Actions Qualitatively Assessed
Ecosystems and Forestry	Protect ecosystem resilience, including forest systems where species will shift	• Conserve and enhance areas representing the full range of wildlife and fish habitats and promote connectivity (e.g., using land exchanges, conservation easements, leases; by removing barriers) to allow species to migrate to suitable habitat.
		• Promote forest conservation, reforestation and urban tree canopy expansion on private and public lands through various means, including funding a statewide forest conservation easement program.
		• Restore wetlands and riparian areas, expand or revise current minimum riparian buffer zones, and implement living shoreline programs to provide natural flood abatement, breeding habitat, and improved stream conditions (including improved thermal conditions).
		• Preserve and create open spaces, parks, and trails that allow people to continue to engage in outdoor activities and maintain connectivity to natural resources. Protect wildlife and fish habitat and species that support recreational opportunities like hunting, fishing, and wildlife viewing.
		• Educate recreational land users about the importance of climate change impacts on ecosystems and the dangers of illegal hunting and fishing, pollution, and development.
		• Retrofit existing parks and trails and create new parks and trails to strengthen the community, improve habitat connectivity, provide more water sources for human users recreating in higher temperatures, enhance natural stormwater and flood management, and connect paths to schools, workplaces, and retail centers to promote pedestrian use.
		• Promote alternatives to mowing, including meadows, native plants, and trees
	Monitor, identify, and address ecosystem vulnerabilities	• Establish a statewide monitoring and research network of academics, civil society, and citizen scientists to establish baseline conditions and monitor ecosystem factors, such as physical changes, species distribution (including invasive species), weather conditions, disease outbreaks, and general ecological conditions, and adequately fund and staff the existing PA Invasive Species Council.
		• Identify and prioritize species, habitat, and ecosystems most vulnerable to climate change and other stressors to better target protection and management actions.
		• Review existing legal, regulatory and policy frameworks that govern protection and restoration of wildlife and fisheries habitats, and identify opportunities to improve their ability to address climate change impacts.
		• Develop a central database to store relevant ecosystem data.
Outdoor Recreation and Tourism	Help the outdoor tourism industry manage shifting climate patterns	• Establish a formal climate change working group building on existing partnerships, comprised of commonwealth agencies, federal agencies, academic institutions, the business community, and environmental non-governmental organizations (NGOs).
		• Help public parks adapt to climate change by designing park infrastructure to be adaptable to changes in use, allocating funds to match recreation demand, and expanding operations at ski resorts to allow for warm-weather recreation.

Sectors	Strategies	Actions Qualitatively Assessed
		• Explore developing new collaboratives with surrounding states.
		• Create a business ombudsman or technical assistance center for affected recreational industries and establish a source of grant funding or tax incentives to help industry and municipalities transition from winter to summer activities.
		• Educate facilities about diversification opportunities for more warm-weather or cold-weather activities (e.g., ski slopes can maintain mountain bike trails for warm weather) with consideration of environmental impacts.
Waste	Reduce waste generation by citizens and business thereby reducing sent to landfills, and WTE facilities, and expand the beneficial use of waste	• Implement programs to encourage citizens and business to reduce waste (including food waste) and use recycling and composting programs through reduce, reuse, and recycle actions.
		• Encourage the use of digesters for methane capture and recovery.
		• Support solar projects on landfill land.
Water	Use stormwater best management practices	• Explore ways to incorporate PA DEP's Stormwater Best Management Practices Manual as standard operating procedure.
		• Provide incentives for the installation and use of gray water and rainwater harvesting and consider existing international guidelines for increased reclaimed, recycled, and gray water use for non-potable applications (e.g., irrigation, toilet flushing).
		• Revise stormwater regulations to accommodate increases in precipitation and run-off
		• Promote green infrastructure by instituting laws, regulations, and local ordinances requiring implementation of green infrastructure with new development or substantial redevelopment and revising the State Revolving Fund (SRF) state ranking criteria to require a thorough analysis and maximization of the use of green infrastructure, where appropriate.
		• Reduce impervious surfaces by requiring installation of permeable surfaces, buffers, and vegetated filters for all transportation-related projects; developing and enforcing a stormwater retention standard for new development and redevelopment; and/or implementing a fee for impervious surfaces.
	Promote integrated water resources management and water conservation	• Support additional research on climate change impacts on water supply and basin hydrology, including with hydrologic models to project changes in surface runoff and groundwater.
		• Assess the impact of climate change on critical water supply and wastewater infrastructure, and encourage the development of facility-specific adaptation plans.
		• Include climate change projections and modeling results in water supply and water quality planning to enhance reliability, improve quality, and improve instream flows and fish passage.

Sectors	Strategies	Actions Qualitatively Assessed
Human Health	Improve reliability and accessibility of public information about climate-related health risks	• Support efforts to develop new surveillance databases and increase data quality and availability, especially for climate-sensitive morbidity.
		• Update Community Health Assessments to include climate change and health tracking metrics.
		• Increase interdisciplinary collaboration among medical and health professionals and other environmental and social scientists to better understand the linkage between climate change and disease.
		• Help local health departments assess their capacity to respond to health threats and to integrate climate preparedness into their hazard response plans and daily operations.
		• Enhance education of health-care professionals to understand the health risks of climate change, including diagnosis and treatment for health outcomes that may become more prevalent.
		• Work locally with vulnerable groups to assist at-risk communities with the development, adoption, practice, and evaluation of response, evacuation, and recovery plans.
		• Regularly map locations of vulnerable populations and use the information to focus interventions and outreach.
		• Review occupational health and safety standards to identify occupations at significant risk due to climate change, and revise as necessary.
	Bolster emergency preparedness and response	• Review existing emergency response, preparedness, evacuation, and management plans.
		• Expand the scope of the state hazard mitigation plan to factor in expected vulnerabilities from climate change impacts.
		• Evaluate and improve the adequacy, effectiveness, accuracy, and technological capabilities of forecasting, early-warning, and emergency-preparedness systems.
		• Foster collaboration between communication service providers and agencies to provide reliable communications in times of power outages and emergencies.
		• Establish heat advisories, increase availability of cooling stations, invest in efficient HVAC systems at targeted Recreation Centers which are provided with renewable energy backup systems, and implement other preventive measures to reduce the impact of extreme heat events.
		• Evaluate the capacity of existing disease prevention programs, enhance surveillance of disease and disease-causing agents, and enhance the capacity of public health programs that control disease-causing agents.
		• Restructure disaster-recovery policies to ensure that redevelopment efforts strive to reduce long-term risk.
Cross-Cutting	Lead by example in commonwealth and local government practices and assets	• Establish a strategic energy management plan for public facilities that includes benchmarking and specific energy, water, and transportation emissions reductions targets and goals.
		• Maximize onsite renewable energy generation and purchase additional renewable power through renewable energy certificates (RECs) direct purchasing.
		• Implement a state-wide benchmarking strategy and platform (such as EnergyStar's Portfolio Manager) for energy and water consumption. Engage the PUC and PA's gas, electric and water utilities to automate billing and utility data input into the selected benchmarking platform, and encourage others (businesses, industry, schools, and municipalities) to implement similar programs to establish their baseline consumption patterns.

Sectors	Strategies	Actions Qualitatively Assessed
		• Establish a state-wide Governor's Sustainability Council and/or interagency workgroup dedicated to the implementation of leadership actions listed in the CAP, as well as actions in department-level plans.
		• Incorporate climate change considerations into decision making processes and criteria. For example, add climate change resilience as a prioritization factor for new capital projects.
		• Consider ENERGYSTAR certification, Leadership in Energy and Environmental Design (LEED) Gold, Net Zero Buildings, Zero Energy Codes, Passive House standards, and climate resilience design guidelines as higher-performance basis of design for new construction and major renovation projects in public buildings.
		• Inventory state buildings and energy use patterns to identify savings opportunities.
		• Implement emissions reduction and climate resilience activities in public facilities, including distributed generation, least impact backup power generation, energy efficiency, water efficiency, climate resilient vegetation, and proper tree maintenance.
		• Require energy efficient and alternative fuels use in fleet vehicles and equipment.
		• Conduct more training, education, and outreach for facility managers and the workforce.
		• Ensure that key government operations have planned to provide least impact backup power supply on-site to protect important security features in the case of more frequent or prolonged blackouts.
		• Highlight climate action already occurring in Pennsylvania and learn from best practice examples within and outside the commonwealth.
	Incorporate historical and projected climate conditions into siting and design decisions for long-term infrastructure	• Establish statewide design guidelines for incorporating climate change, similar to New York City's design guidelines (NYC Mayor's Office of Recovery and Resiliency 2018).
		• Integrate climate change considerations into agency-level capital planning processes and seek to ensure that state investments in infrastructure and development projects (direct or indirect) reflect potential climate change impacts, especially future risk projections.
		• Implement new or modified policies (e.g., zoning regulations, tax incentives, and rolling easements) that encourage appropriate land use and reduce repetitive losses.
		• Develop or update floodplain mapping using the best available science and accounting for the impacts of climate change.
		• Adopt insurance mechanisms and other financial instruments, such as catastrophe bonds, to protect against financial losses associated with infrastructure losses.
		• Encourage owners and operators of critical energy infrastructure to evaluate vulnerability to the impacts of climate change, including the risk of damage; the potential for disruptions and outages from flooding, sea level rise, extreme heat, drought, erosion and other extreme weather events; and the impacts of new climate change weather data on energy demand.

3 Emission Reduction and Adaptation Opportunities

This section of the report presents Pennsylvania's expected climate change impacts, as well as opportunities to reduce emissions and adapt to these impacts in the following sectors:

- Energy Consumption
- Energy Production
- Agriculture
- Ecosystems and Forestry
- Outdoor Recreation and Tourism
- Waste Management
- Water Resources
- Human Health

Each sector section includes:

- Sector background and relevance in Pennsylvania
- Climate impacts for the sector
- Opportunities to adapt and reduce emissions, by strategy

Each strategy includes:

- A brief description of the strategy
- A list of actions that state and local leaders can take to support the strategy
- A summary of strategy benefits and costs including both quantitative and qualitative assessments of climate resilience, environmental, and economic benefits and costs
- Performance indicators and metrics that Pennsylvania could use to measure progress toward the strategy
- Color-coded text boxes outlining actions that citizens and businesses can take to support the strategy

Energy Consumption

End-use energy consumption is the largest source of GHG emissions in Pennsylvania. Energy is consumed in four principal sub-sectors:

Sector	Major End Uses
Transportation	Personal vehicle and fleet motor fuels and electricity use
Residential	Fuels and electricity for space conditioning, water heating, appliances, lighting, electronics
Commercial	Fuels and electricity for space conditioning, water heating, lighting, office equipment, IT systems
Industrial	Fuels and electricity for process technologies, motor systems, lighting

The transportation sector was the greatest consumer of energy in the commonwealth between 2000 and 2012, but as of 2013, the industrial sector became the largest consumer, followed by the transportation, residential, and commercial sectors.

Industrial facilities vary in their energy needs depending on processes and other end-uses occurring at a given facility. They tend to use some combination of electricity, natural gas, petroleum such as residual or distillate fuel oils, coal, and renewable sources. Most industrial facilities purchase electricity from utilities, but some generate their own electricity on site.

In residential buildings, the greatest energy end-use is for space conditioning while electronics, lighting, and other appliances account for a large portion of total electricity consumption. Water heating, air conditioning, and refrigeration make up the bulk of the remaining residential consumption. Natural gas and electricity are the most-consumed energy sources in residential buildings, but heating oil, coal, wood, and propane are also used in some areas (EIA 2013).

As is the case in residential buildings, space conditioning is largest consumer of energy in commercial buildings, however the energy use breakdowns for commercial sector vary considerably based on the type of building. Offices have different energy needs than schools, which have different needs than shopping malls and warehouses. Generally, electricity and natural gas are the primary energy sources in commercial buildings (EIA 2017c).

Transportation energy use includes the petroleum products, biofuels, natural gas, and electricity used to power various modes of transportation across Pennsylvania (EIA 2018). Motor gasoline, the most-consumed fuel in Pennsylvania, and diesel fuel power cars, motorcycles, trucks, buses, trains, and boats, while jet fuel is used to power commercial airplanes. Some vehicles utilize alternative fuels like compressed or liquefied natural gas, biodiesel or ethanol, and increasingly, electricity.

Climate Change Impacts

The expected impacts of climate change on energy consumption in Pennsylvania (Shortle et al. 2015) include:

- Increased demand for energy, particularly electric power, due to higher temperatures during summer months. This could result in higher energy costs for consumers.
- Decreased heating energy demand due to higher temperatures during winter months, though Shortle et al. show this decrease is not expected to offset the increase in cooling energy demand.
- Disruptions to energy supply chains due to extreme weather events such as floods, severe storms, or severe temperatures. This could result in decreased power grid reliability.
- Disruptions to the transportation network due to extreme weather events, which could affect transportation reliability overall and, in turn, could affect transportation system energy consumption.

Opportunities to Reduce Emissions and Adapt to Climate Change

In the Energy Consumption sector, the analysis team has identified three main strategies to reduce emissions and adapt to climate impacts:

- **Increase end use energy conservation and efficiency**
- **Implement sustainable transportation planning and practices**
- **Develop and implement financing options to encourage energy efficiency**

These Energy Consumption strategies include seven actions that were quantitatively analyzed (see Table 5 below). Together, these seven actions are expected to result in:

- Annual GHG reductions in 2025: **6,889,187 $MTCO_2e$** (3% reduction from 2005 levels of 262,602,782 $MTCO_2e$)
- Annual GHG reductions in 2050: **37,005,093 $MTCO_2e$** (14% reduction from 2005 levels of 262,602,782 $MTCO_2e$)

GHG reductions and cost per ton of GHG reduced (a measure of cost-effectiveness), by strategy and individual action, are presented in Figure 9 and Table 5 below.

Figure 9. Annual GHG Reductions Compared to BAU Through 2050 for Energy Consumption Strategies and Actions ($MMTCO_2e$)

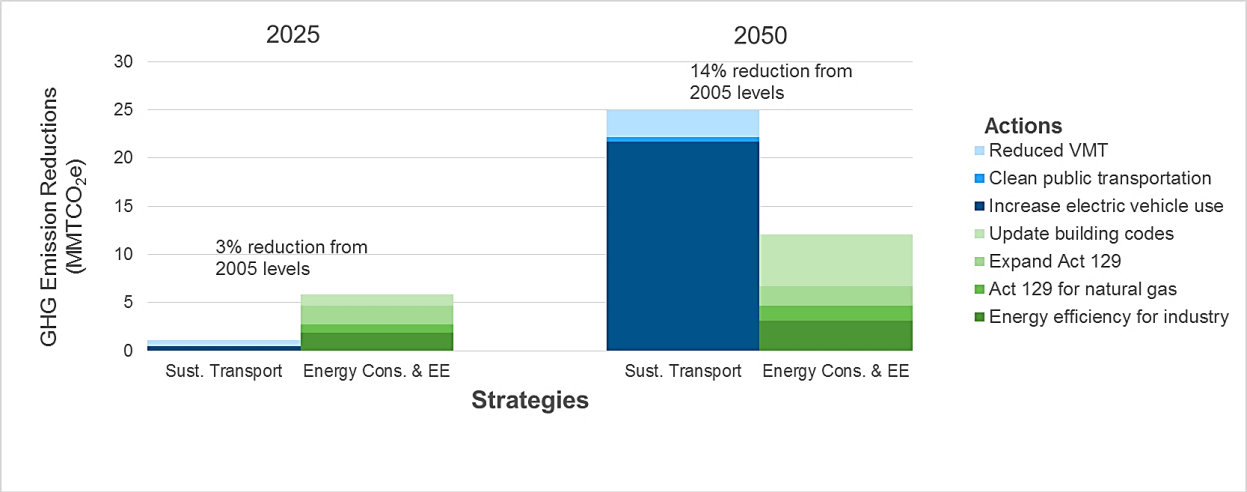


Table 5. Annual GHG Reductions in 2025 and 2050 and Cost per Ton of GHGs Reduced for Energy Consumption Strategies and Actions

Strategies and Actions Included in Higher-Level Strategy Quantitative Modeling	Annual GHG Reductions in 2025 ($MTCO_2e$)	Annual GHG Reductions in 2050 ($MTCO_2e$)	Cost per Ton of GHG Reduced ($/ton of CO2e)
Increase end use energy conservation and efficiency	**5,827,879**	**12,036,172**	**-$127**
Update building codes	1,164,587	5,374,682	-$199
Increase adoption of energy efficiency, including by expanding Act 129	1,916,947	1,984,261	-$198
Create an Act 129-like conservation and efficiency program for natural gas	845,010	1,567,198	-$119
Expand energy assessments and provide more trainings on energy efficiency for industry	1,901,335	3,110,031	$8
Implement sustainable transportation planning and practices	**1,061,309**	**24,968,921**	**$71**
Reduce vehicle miles traveled for single-occupancy vehicles	573,260	2,820,936	-$447
Implement a strategic plan and incentives for increasing electric vehicle use	474,100	21,689,937	$151[a]
Increase the use of clean public transportation through electric municipal bus fleets	13,948	458,048	$1,022

[a] *No state or federal incentives were included in the cost-per-ton estimate for vehicle electrification due to the uncertainty of their availability. However, if available, incentives could substantially reduce the cost-per-ton of implementing these actions.*

Notes: Negative cost-per-ton represents net cost savings.

Increase End Use Energy Conservation and Efficiency

End-use energy is the energy consumed by the user, including electricity, gasoline, and natural gas. Energy usage may be reduced through conservation and efficiency measures that result in environmental and economic benefits. Energy conservation, which includes behavioral and operational measures and programs, such as changing temperature settings, turning off unused lights and energy consuming devices, reducing the operation hours for space conditioning and energy systems, and changing industrial process operations, is less costly to implement, easiest to accomplish, and has instant–though often smaller–economic benefits compared to energy efficiency measures. Energy efficiency, which this strategy mainly focuses on, includes improving the overall and operating performance of building envelopes (e.g., better windows, insulation, and air sealing), kitchen and laundry appliances, lighting (e.g., LED and other advanced technologies), heating and cooling systems (e.g., ground-source heat pumps, variable refrigerant flow, and ductless systems), as well as influencing the behavior of consumers to reduce their energy use. Reducing energy demand through energy efficiency or conservation can help offset some of the expected increases in energy demand due to higher temperatures, helping individual consumers and the grid overall.

Leadership Actions

State and local leaders can increase energy efficiency by requiring and/or incentivizing more energy efficient design standards and technologies, as well as by improving efficiency of government-owned facilities and equipment (see Lead by Example strategy). For example, leaders can:

- **Update building codes** and allow or incentivize local "stretch" code adoption and high performance/net zero buildings. The commonwealth's legally defined process for energy codes adoption is summarized below. In the future the Pennsylvania legislature could enact measures similar to its 2017 law enabling the City of Philadelphia an exception to adopt and more stringent commercial energy codes. States like New York and Massachusetts allow local jurisdictions to adopt "stretch" codes that exceed state legal minimum stringency. In addition, local governments can use their other development policy powers, such as density bonus incentives, to encourage higher-efficiency new construction.
    - **Residential.** The Department of Labor and Industry (L&I) could use its authority to promulgate and upgrade the Pennsylvania Uniform Construction Code (UCC), through modifications subject to public hearings and approval by the L&I Review and Advisory Council (RAC). Residential energy code provisions are based the International Code Council (ICC)'s triennial International Energy Conservation Code (IECC) and International Residential Code (IRC) triennial code updates.
    - **Commercial.** L&I could update the commercial energy code provisions through the same overall process, but draw on the IECC's commercial provisions, as well as those of ASHRAE Standard 90.1. In addition, 2017 state legislation enabled the City of Philadelphia to adopt a more stringent code for commercial buildings.

- **Increase adoption of energy efficiency, and expand Act 129** to increase targets, increase or eliminate cost caps,[5] and create beneficial programmatic changes.[6] The legislature could act to increase the annual savings targets set in the original Act 129 legislation. Increasing the impact of Act 129 programs would also need complementary state legislative or regulatory action to reform ratemaking and resource acquisition policies, such that utilities would have better financial results by investing in energy efficiency.
- **Create an Act 129-like conservation and efficiency program for natural gas.** To implement this action, the Pennsylvania legislature needs to pass legislation that creates an Energy Efficiency Resource Standard (EERS) for natural gas. In creating a natural gas EERS, lawmakers could look to other states that have created similar programs, such as the 2011 EERS enabled by the Green Communities Act in Massachusetts (https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter169), or the recently enacted EERS in New Jersey through Bill A3723 (https://legiscan.com/NJ/bill/A3723/2018) (ACEEE 2018).

  Using a format similar to the Act 129 requirements, natural gas EERS legislation would set annual incremental natural gas savings targets for regulated natural gas distribution companies, and establish a set planning cycle and implementation periods.

  Note that, while not driven by legislative mandate, four of the largest natural gas companies in Pennsylvania, serving greater than 50 percent of Pennsylvania's residential gas customers, do provide Energy Efficiency and Conservation programs and this trend is growing.
- **Expand energy assessments and provide more trainings on energy efficiency for industry**. This action could be tied to the future of Act 129-type EERS policies for electricity and gas. As savings targets increase, and complementary policies are instituted, Pennsylvania utilities will be both better enabled and more motivated to seek energy efficiency solutions in the industrial sector. To drive energy performance in such large organizations developing a comprehensive approach to energy management is necessary. One of the most promising frameworks for this kind of effort is Strategic Energy Management (SEM), which states like New York support through its NYSERDA (New York State Energy Research and Development) Strategic Energy Management Program (https://www.nyserda.ny.gov/All-Programs/Programs/Strategic-Energy-Management). A statewide SEM program would help companies set up comprehensive programs with goals, metrics, and analytics tools to drive operational improvements as well as efficiency investments. It would help large customers take advantage of utility programs while also driving savings across the entire organization.

[5] Lifting cost caps could increase short-term rate impacts, but if the measures are designed to be cost-effective and reduce consumption, total customer costs would still be lower over the lifetime of the measures.
[6] Act 129 is extremely cost-effective and generally reduces the costs of other policies; e.g., reducing electricity usage below BAU levels reduces the cost of serving that load with renewable energy.

The above actions in **bold** are reflected in the quantified key metrics below. Other actions leaders can take include:

- Expand home weatherization programs beyond those currently identified as low-income households and provide greater penetration of these programs for those currently eligible.
- Increase financial and technical support for market trends for energy efficient technologies such as LED indoor and street lighting and automated control systems.
- Replace high carbon and GHG producing fuels or energy sources with less environmentally impactful options.[7]
- Educate consumers about the benefits of occupant performance and low energy usage improvements in building system technologies.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

Increased energy efficiency can offset some of the increases in energy demand due to higher cooling needs. This, in turn, can:

- Reduce the strain on the overall energy system, particularly during peak loads—enhancing electricity grid reliability, reducing the risk of power outages, and reducing operating costs for utilities.
- Reduce energy costs for Pennsylvania citizens and businesses—particularly important if electric bills would otherwise increase due to higher temperatures.
- Reduce criteria air pollutant emissions, the health impacts of which could be exacerbated by higher temperatures (Shortle et al. 2015).

Several building design elements can also make buildings more resilient to energy supply disruptions and droughts. For example, passive design features can reduce the need for mechanical heating or cooling during outages, and water efficiency and recycling can reduce water demand during times of drought.

Environmental Benefits & Costs

In addition to the effects quantified in this report, energy efficiency in buildings can provide environmental benefits in the form of improved indoor air quality. Some building upgrade methods are designed to address issues related to moisture and mold, and these can improve indoor air quality and occupant health.

[7] In some instances, for example electrification of heating systems (replacing heating oil), actions may counteract each other; in this example switching to electric heating increases electricity use, which is counter to the intention of Act 129.

Economic Benefits & Costs

In addition to quantified effects such as increases in income and employment, efficiency is known for creating local economic benefits in the form of investment and jobs within a community. A recent analysis showed that Pennsylvania employs more than 65,000 people in the energy efficiency industry (E2 2018). Some energy investments generate most of their effects in locations outside of Pennsylvania; efficiency, however, can be implemented in almost any jurisdiction, thus providing additional social equity in the distribution of economic benefits.

Key Metrics

Net Present Value: $37,487 Million[a]

Cost-per-ton of GHG Reduced: - $127/$MTCO_2e$[b]

	2025	2050		2025	2050
	GWh Electricity Consumption Reduced			***BBtu Nat. Gas Consumption Reduced***	
	10,638	31,160		38,255	109,927
	$MTCO_2e$ GHG Emissions Reduced			***MT Air Pollutant Emissions Reduced***	
	5,827,879	12,036,172	NO_x	4,774	7,164
			SO_2	7,612	10,178
			Hg	0.14	0.16
	Capital Expenditures ($ Million)			***Program Costs ($ Million)[c]***	
	$1,059	$1,143		$463	$488
	Number of Jobs Supported			***Impact on GSP ($ Million)***	
	8,691	19,793		$695	$1,561
	Increase in Disposable Personal Income Per Household ($/Household)			***Energy Expenditure Savings ($Million)[d]***	
	$105	$267		$1,6389	$5,309

[a] *Net Present Value for this strategy includes capital expenditures, energy savings, and program costs.*

[b] *A negative "cost-per-ton" indicates cost savings.*

[c] *Program Costs include incentives and administrative expenses*

[d] *Energy Expenditure Savings in this strategy represent energy bill savings on fuels and electricity.*

Key Analysis Assumptions:

- *Quantified metrics reflect the policies, programs, and actions in* **bold** *above.*
- *Future versions of building codes for residential (base code IECC 2009) and commercial (base code ASHRAE 2007) new construction are implemented every six years through 2050 with a 90 percent compliance rate.*
- *Energy efficiency improvements, including by expanding Act 129, are estimated by relying on maximum achievable potentials presented in the Pennsylvania Statewide Evaluator's (SWE) Energy Efficiency Potential Study for Pennsylvania (PA PUC 2015). For residential the maximum achievable potential is*

1.5 percent from 2021-2050; for commercial the maximum achievable potential is 0.8 percent from 2021-2025, followed by 1.0 percent annual incremental savings for years 2026-2050.

- *Efficiency and conservation programs for natural gas, similar to Act 129, are modeled based on a national review of state energy savings targets for natural gas efficiency policies and the Massachusetts EERS target of 1.1 percent annual incremental natural gas savings from 2020-2025 followed by 1.0 percent from 2026-2050 (ACEEE 2017).*
- *Efficiency and conservation improvements for industry are aligned with the maximum achievable potentials presented in the Pennsylvania Statewide Evaluator's (SWE) Energy Efficiency Potential Study for Pennsylvania (PA PUC 2015) for electricity (annual 1.2 percent through 2050) and in a Georgia Institute of Technology study (GIT 2009) for natural gas (annual 0.6 percent through 2050).*

Other Key Performance Indicators

In addition to the metrics listed above, example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Monthly and annual purchased energy
- Final energy or electricity consumption per person served/floor area served for a particular sector
- Energy productivity–nationally, this is GDP per unit of total primary energy consumed
- Energy intensity–energy consumed per unit of work done or square footage
- Electricity or natural gas total energy unit savings from efficiency
- Investment in energy efficiency
- Absolute amount of energy consumed
- Costs of residential, commercial, and industrial energy bills

What You Can Do to Increase End Use Energy Conservation and Efficiency

Pennsylvania citizens can support this strategy by taking the following actions:

- ► Install energy efficient lighting and appliances.
- ► Conduct a home energy audit to identify other efficiency opportunities.
- ► Install smart thermostats, home energy management systems, and other smart controls.
- ► Avoid energy intensive activities during peak times (especially late afternoon and evening). For example, run appliances (e.g., dishwashers, dryers) during utility off-peak hours.
- ► Practice energy conservation by moderating temperature settings, turning off unused devices and lights, unplugging devices when not in use or charging, and using natural light when available.
- ► Conduct regular maintenance on HVAC systems to ensure optimal operation and energy use.

What Businesses Can Do to Increase End Use Energy Conservation and Efficiency

Pennsylvania businesses can support this strategy by increasing the energy efficiency of business operations. See examples of actions in the "What You Can Do" box above.

In addition, businesses in the following industries can play a role in supporting this strategy by taking the following actions:

Construction Professionals and Designers

- Construct buildings to protect against projected changes in climate through measures such as efficient orientation, insulation, windows, and other features that reduce energy demand and provide resiliency benefits.

Utilities

- Deploy energy efficiency programs to reduce emissions overall and counteract the increase in peak demand due to increased use of air conditioning.
- Invest in smart grid technology, including energy storage to increase renewable power generation, and demand response programs to help customers cut their peak power usage.

Commercial Office Buildings

- Enable power management functions on IT systems and utilize sleep settings on electronic office equipment.
- Consolidate stand-alone office equipment and use smart power strips.
- Commission and periodically re-tune buildings.

Implement Sustainable Transportation Planning and Practices

Considering climate changes in long-range transportation planning and transportation infrastructure design improves the chances that infrastructure will be planned and designed for the conditions it will experience over its lifetime. This is particularly important for long-lived or capital-intensive infrastructure.

Leadership Actions

The Commonwealth of Pennsylvania plans to advance this strategy by pursuing a selection of the following policies, programs, and actions. Actions in bold are reflected in the quantified key metrics below:

- **Reduce vehicle miles traveled for single-occupancy vehicles** by promoting, expanding opportunities for, and incentivizing ride sharing, walking, bicycling, and public transit options.

  Pennsylvania has one of the highest gasoline taxes of any state in the country. While this tax can contribute to a reduction in overall fuel use, or even changing trends in types of purchased vehicles, it is not enough to reduce VMT over the study period. In urban and suburban centers programs to incentivize alternative modes of transportation, including ride sharing, walking, bicycling, and public transit could help reduce VMT. Pennsylvania is already in the process of updating its Bicycle and Pedestrian Master Plan (https://www.penndot.gov/TravelInPA/RideaBike/Pages/Master-Plan.aspx), and this update presents an opportunity for the commonwealth to become more ambitious in programs and policies to replace single occupancy trips with alternative transportation modes. The

commonwealth could also consider other means for incentivizing alternative transportation modes, such as working with major companies and employers to provide expanded or new incentives for using public transportation (such as incentives provided in New Jersey (http://www.transoptions.org/employers-pretax-commuter-incentives)), or car or van pooling, building on efforts already going on such Commute PA (https://pacommuterservices.org/commutepa/) or Vanpooling (https://pacommuterservices.org/vanpool/). Penalties are also a mechanism which could be used to discourage single occupancy vehicle trips and encourage carpooling, such expanding on the use of high occupancy vehicle lanes like the ones implemented by the Pennsylvania Department of Transportation (PennDOT) on I-279 (https://www.penndot.gov/RegionalOffices/district-11/Pages/HOV.aspx) or the newly installed on-demand toll charging for I-66 (http://www.transform66.org/splash.html) in Virginia during rush hour, a main artery from Virginia into DC. HOV lane requirements could also be expanded upon, such as increasing the required number of passengers from 2 to 3 (e.g., as done on parts of I-95 and offshoots of it (http://www.virginiadot.org/travel/hov-novasched.asp#I-495%20Express%20Lanes)). These changes would be implemented by PennDOT and operators of tolls and systems (e.g., the Pennsylvania Turnpike Authority). Additionally, incentives for public and private sector telecommuting, including business tax incentives and encouragement for setting schedules for telecommuting for individuals and teams is another mechanism that can be used to reduce VMT during the work week.

In Pennsylvania, there are 37 urban and rural fixed transit agencies and 26 agencies that only provide community/demand response transportation. (As defined in 49 C.F.R Section 604.3(g): "Demand response" is any non-fixed route system of transporting individuals that requires advanced scheduling by the customer, including services provided by public entities, nonprofits, and private providers.) Many of the fixed route agencies also provide community/demand response transportation. These agencies also play a vital role in VMT reduction and transportation demand planning and response.

- **Implement a strategic plan and incentives for increasing electric vehicle use** in line with the PA's Electric Vehicle Roadmap (PA DEP 2018a). Tactics might include: encouraging workplace charging; incentivizing the purchase of alternative, low, and zero emissions vehicles through financial mechanisms or programs; and expanding electrification for off-road applications, including vehicles, construction, and materials handling equipment. More specifics for implementing this action can be referenced in the Electric Vehicle Roadmap.
- **Increase the use of clean public transportation through electric municipal bus fleets**.

  Now is the right time for Pennsylvania and its local governments to assess the role of electric municipal bus fleets–according to a May 2018 Bloomberg New Energy Finance Research article (https://about.bnef.com/blog/e-buses-surge-even-faster-evs-conventional-vehicles-fade/): "The electrification of road transport will move into top gear in the second half of the 2020s, thanks to tumbling battery costs and larger-scale manufacturing, with sales of electric cars racing to 28%, and those of electric buses to 84%, of their respective global markets by 2030." The same

article also states that: “The advance of e-buses will be even more rapid than for electric cars, according to BNEF’s analysis. It shows electric buses in almost all charging configurations having a lower total cost of ownership than conventional municipal buses by 2019.” Most of the responsibility for increasing the use of electric buses in municipal fleets falls to cities, municipalities, or local transit authorities (e.g., the Southeastern Pennsylvania Transit Authority (SEPTA)). In the populated urban and suburban areas of Pennsylvania, great strides are already being made to electrifying bus fleets. For example,

- SEPTA will soon have the largest fleet of electric buses on the East Coast, with 25 electric buses scheduled to be delivered (PA DEP 2018a).
- The Port Authority of Allegheny County will buy its first electric bus with a federal grant to test the technology for potential use on its BRT route opening in 2020 (PA DEP 2018a).

There are opportunities at the state-level to help amplify local efforts. For example, the Driving PA Forward program provides opportunities to help finance clean transportation vehicles and infrastructure. Additionally, the Pennsylvania legislature and DEP could choose to expand programs such as AFIG to make larger amounts of funding available to municipal authorities or offer additional support to these municipal authorities in completing AFIG applications. See also information in DEP’s Electric Vehicle Roadmap (PA DEP 2018a).

The above actions in **bold** are reflected in the quantified key metrics below. Other actions leaders can take include:

- Develop people-mover[8] systems, such as West Virginia University’s Personal Rapid Transit system.[9]
- Continue and expand efforts to assess climate risks to transportation and land use planning, and incorporate expected future conditions into capital planning, project design, and routine operations, maintenance, and inspection practices.
- Improve preparedness for increased frequency of extreme events by improving coordination between agencies and other stakeholders and by improving real-time monitoring of flooding, traffic, and other conditions.
- Prioritize and provide guidance to local governments on transportation and land use planning that promotes efficient use of public resources, encourages walkable development, reduces congestion, and minimizes greenhouse gas emissions through multi-modal transportation networks and compact, transit-oriented development that uses smart growth practices and complete streets.

[8] People movers are small scale automated guideway transit systems.
[9] https://transportation.wvu.edu/prt

- Educate citizens and business on the benefits of transportation demand-side management measures and clean and efficient transport options.
- Increase adoption of people-powered transportation options such as walking school buses[10] or commuter bicycle paths.
- Reduce non-CO_2 emissions (hyrdofluorocarbons) from truck and stationary refrigeration systems.
- Participate in the Transportation Climate Initiative and help develop and implement regional market-based policies that would both reduce carbon pollution from the transportation sector and fund clean transportation investments. On December 18, 2018, Pennsylvania signed on to the Transportation Climate Initiative's latest statement and committed to designing a regional low-carbon policy proposal for the Northeast's transportation sector.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

Implementing sustainable transportation planning and practices can:

- Help the transportation network avoid or recover quickly from disruptions due to extreme events.
- Improve the reliability of the transportation network. Providing alternative transportation routes, modes, and fuels can increase the nimbleness of the transportation sector overall to transport goods and people even if an extreme event disrupts some parts of the system.
- Reduce Pennsylvania's dependence on gasoline-based transportation, thereby reducing citizen exposure to potential future increases in global oil prices.
- Reduce transportation system disruptions due to flooding and extreme events because transportation system planning accounts for expected climate change impacts.

Environmental Benefits & Costs

In addition to the benefits quantified in this report, sustainable transportation can create other beneficial effects, such as reduced noise and reduced congestion particularly in urban areas. To the extent that such strategies reduce total road area, they can also reduce the environmental effects associated with paving materials, and with water runoff from impervious surfaces.

Economic Benefits & Costs

The economic benefits and costs of this strategy will vary depending on the specific actions taken. Many of the actions to integrate climate risk into existing processes can be implemented at very low cost. Strategies to change the design of a specific transportation asset may be costlier, and cost effectiveness should be assessed on a case-by-case basis. Job benefits can be substantial: a recent study showed that clean vehicle businesses employ almost 7,000 people in Pennsylvania (E2 2018). Sustainable transportation can also create social equity benefits, to the extent that economically-disadvantaged

[10] Walking buses are where parents walk from house to house and pick up kids on the way to a neighborhood school, in lieu of using a bus.

populations would have greater mobility, bringing increased access to employment and other opportunities.

Strategies to increase the resilience of the transportation system to flooding would have up-front capital costs, but also represent an opportunity for economic savings if the strategies can reduce flood-related damage and disruptions. PennDOT, for example, has spent over $190 million in state and federal funds since 2006 to recover from flood-related disasters (PennDOT 2017). These costs do not capture the economic costs of transportation service disruptions.

Key Metrics

***Net Present Value:* -$20,397 Million[a]**

***Cost-per-ton of GHG Reduced:* $71/$MTCO_2e$**

	2025	2050		2025	2050
	GWh Electricity Consumption Increased			***BBtu Fossil Fuel Consump. Reduced[b]***	
	1,330	42,412		21,387	465,152
	BBtu Biodiesel Consumption Reduced				
	12	283			
	$MTCO_2e$ GHG Emissions Reduced			***MT Air Pollutant Emissions Reduced***	
	1,061,309	24,968,921	NO_x	1,606	7,210
			SO_2	-956	-14,950
			Hg	-0.02	-0.20
	Capital Expenditures ($ Million)			***Public Expenditures ($ Million)[c]***	
	$2,078	$6,374		$151	$695
	Maint. & Repair Cost Savings ($ Million)				
	$302	$2,876			
	Number of Jobs Supported			***Impact on GSP ($ Million)***	
	-4,015	8,394		-$262	$1,561
	Change in Disposable Personal Income Per Household ($/Household)			***Energy Expenditure Savings ($Million)[d]***	
	-$41	$131		$286	$4,383

[a] *Net Present Value for this strategy includes capital expenditures, energy savings, and maintenance and repair cost savings.*

[b] *This strategy affects natural gas, distillate fuel oil, and motor gasoline consumption.*

[c] *Public Expenditures are the subset of capital expenditures associated with electric vehicle supply equipment (EVSE) expected to be funded by the commonwealth. These expenditures are also included in Capital Expenditures.*

[d] *Energy Expenditure Savings in this strategy represent savings on natural gas, diesel fuel, motor gasoline, and electricity expenditures.*

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU. Negative cost-per-ton represents net cost savings.

Key Analysis Assumptions:

- *Quantified metrics reflect the policies, programs, and actions in* **bold** *above.*
- *Overall vehicle miles traveled (VMT) are reduced 3.4 percent by 2030 and 7.5 percent of total VMT from BAU by 2050. This estimate is based on the draft Pennsylvania Energy Assessment Report prepared in 2018, as well as Pennsylvania-specific runs of the EPA's MOtor Vehicle Emission Simulator (MOVES), U.S. Energy Information Administration's (EIA) Annual Energy Outlook (AEO) 2018, and Federal Highway Administration VMT projections (EIA 2018, FHWA 2018).*
- *EVs are 31 percent of the light-duty market share by 2030, rising to 88 percent by 2050. The target is based on a review of the U.S. EIA's AEO 2018 national-level projections, as well as the Pennsylvania DEP report Pennsylvania Electric Vehicle Roadmap, with consideration for the current market share (EIA 2018, DEP 2018a).*
- *25 percent of new municipal transit bus purchases are zero emission buses, using battery electric technology, by 2030, increasing to 60 percent by 2050. This projection is based on zero emission transit bus market penetration projections from CALSTART as well as various state targets (CALSTART 2015).*

Other Key Performance Indicators

In addition to the metrics listed above, example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Number of people using public transportation/biking/walking
- Vehicle miles traveled per capita
- Carbon intensity (transportation CO_2 emissions per capita)
- Fuel saved with fuel-efficient vehicles (including EVs)
- Number of EVs registered in Pennsylvania

What You Can Do to Implement Sustainable Transportation Planning and Practices

Pennsylvania citizens can support this strategy by taking the following actions:

- ► Choose alternative forms of transportation when possible, including public transit, carpooling, walking or biking.
- ► Purchase a more fuel-efficient or low-emission vehicle (e.g., a battery electric vehicle) and/or combine trips to save money and reduce greenhouse gas emissions.
- ► Maximize the fuel economy of your vehicle by performing proper maintenance and ensuring tires are correctly pressurized.
- ► Support sustainable transport by participating in transportation planning processes with your local government or metropolitan planning organization.
- ► Participate in telework programs that may be offered by your employer.

What Businesses Can Do to Implement Sustainable Transportation Planning and Practices

Pennsylvania businesses can support this strategy by taking the following actions:

- Purchase fuel-efficient or low-emission vehicles (including fleets) to save money and reduce GHG emissions.
- Support sustainable transport by participating in transportation planning processes with your local government or metropolitan planning organization.
- Provide incentives to employees for smart commuting practices and allow for teleworking, where feasible.

Develop, Promote, and Use Financing Options to Encourage Energy Efficiency

Upfront costs can be a major barrier to implementing clean energy or energy efficiency projects. An important goal of efficiency policies and programs is to help minimize these upfront project costs, encouraging owners to invest in energy efficiency improvements and retrofits. Several financing strategies are available to pursue this goal.

Leadership Actions

The Commonwealth of Pennsylvania could advance this strategy by pursuing a selection of the following policies, programs, and actions:

- Expand use of performance contracting.
- Create state and local clean energy tax incentives.
- Establish/expand residential energy efficiency loan programs similar to Keystone HELP.
- Engage in public-private partnerships (P3) to leverage private capital for infrastructure investment.
- Encourage/require utilities to provide on-bill financing or repayment.
- Fund a state green bank (e.g., New York, Connecticut Green Banks).
- Encourage broad local government implementation of recent state commercial PACE legislation.
- Explore residential PACE program options within federal policy constraints.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

Clean energy financing options, while they don't create benefits by themselves, can be important enabling mechanisms to help advance clean, distributed energy, which in turn can create the following benefits:

- Reduce the frequency or length of power outages from extreme events due to the distributed nature of clean energy. Communities and businesses experience substantial losses during power outages.

- Protect vulnerable communities from loss of critical services due to extreme events.
- Reduce strain on the energy grid through energy efficiency measures.
- Lower long-term energy costs.

Environmental Benefits & Costs

Financing, while it does not produce environmental effects directly, can help accelerate clean energy technology investment, thus providing indirect environmental benefits.

Economic Benefits & Costs

Financing can supplement the economic benefits of a range of clean energy technologies, by providing the capital needed to increase market activity. To the extent that financing increases total market uptake of a given technology, it indirectly helps increase total investment, total employment, and the other benefits described elsewhere in this report. Financing also provides direct employment benefits by increasing job opportunities for loan officers, underwriters, and servicing entities.

Key Performance Indicators

Example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Total rebates or incentives received
- Number of customers who participate in on-bill financing programs or in incentive or rebate programs
- Number of clean energy projects that use financing options Strategy Benefits and Costs

What You Can Do to Develop, Promote, and Use Clean Energy Financing Options

Pennsylvania citizens can support this strategy by taking the following actions:

- ► Utilize available utility rebates or tax incentives for energy efficiency or renewable energy projects.
- ► Request utilities to allow on-bill financing or repayment to streamline financing of energy efficiency projects.

What Businesses Can Do to Develop, Promote, and Use Clean Energy Financing Options

Pennsylvania businesses can support this strategy by taking the following actions:

- ► Develop public-private partnerships with local or state government agencies to develop business opportunities and help entities finance clean energy projects.
- ► Utilize the new commercial PACE financing mechanism, when implemented in your locality, to help pay for energy efficiency and renewable energy projects.

Energy Production

Pennsylvania is the third-largest energy producing state in the U.S. behind Texas and Wyoming (EIA 2017b). Pennsylvania is the third-largest coal-producing state in the nation as well as second in electricity generation from nuclear power (EIA 2017a).

In the past, coal and nuclear were the predominant fuels for generating electricity. However, Pennsylvania's significant growth in natural gas production has resulted in a marked decrease in coal-fired electricity generation. This shift has occurred, in part, because technological advancements in hydraulic fracturing made it possible to develop natural gas resources that were previously uneconomic, thus driving down the price of natural gas. Now, Pennsylvania is the nation's second-largest natural gas producer (EIA 2017a). Pennsylvania is the largest exporter of electric power generation in the U.S., with approximately one third of the electricity generated in the state being exported (EIA 2017B).

Meanwhile, renewable and alternative energy production is experiencing its own boom in the commonwealth. One of the drivers behind this boom is the existing AEPS in Pennsylvania, which was established in 2004 and requires that electric distribution companies and electric generation suppliers ensure that by 2021 a minimum of 18% of total electric supply is from qualified renewable and alternative energy resources. Decreasing costs of technology are also helping to drive the increases in renewable power generation.

Climate Change Impacts

The expected impacts of climate change on energy production in Pennsylvania (Shortle et al. 2015) include:

- Increased strain on the energy sector to produce reliable supplies, particularly for power generation facilities that require cooling water, due to increased seasonal variations in freshwater and higher peak electricity demand. This could result in potential disruptions to power for citizens and businesses and increases to the cost of energy.
- Reduced energy delivery reliability, damaged infrastructure, or equipment failures due to extreme weather events such as floods, severe storms, or extreme temperatures.

Opportunities to Reduce Emissions and Adapt to Climate Change

In the Energy Production sector, DEP has identified four main strategies to reduce emissions and adapt to climate impacts:

- **Increase use of clean, distributed electricity generation resources**
- **Create a diverse portfolio of clean, utility-scale electricity generation**
- **Reduce impacts of fossil fuel energy production and distribution**
- **Increase production and use of alternative fuels**

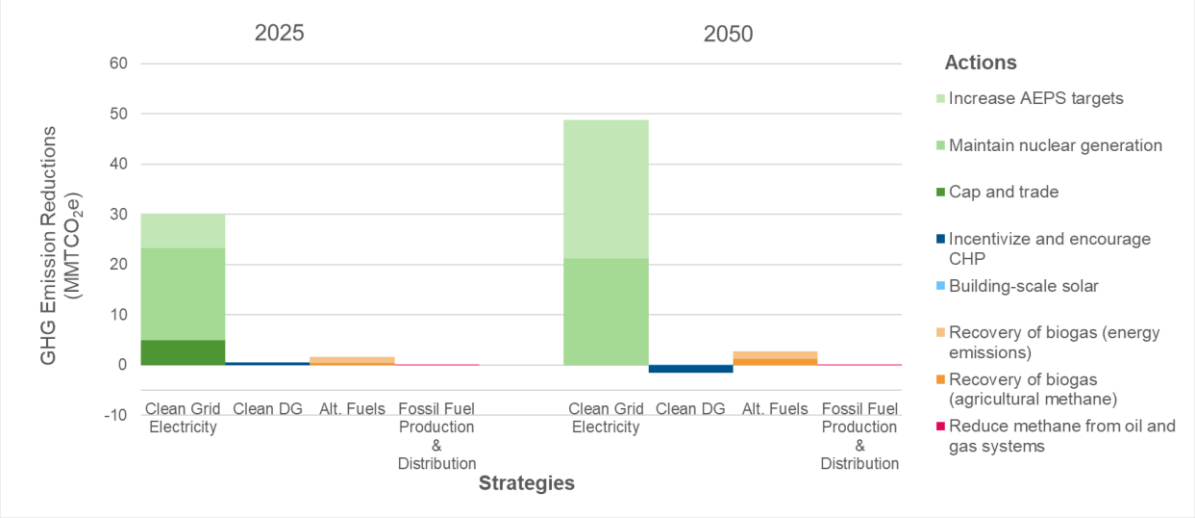
Each strategy description below includes leadership, citizen, and business actions that support the strategy; a summary of strategy benefits and costs; and key performance indicators.

In addition, these Energy Production strategies include seven actions that the team quantitatively analyzed (see below). Together, these seven actions are expected to result in:

- Annual GHG reductions in 2025: 31,391,440 MTCO2e (12% reduction in energy consumption emissions and 6% reduction in energy production emissions from 2005 levels of 262,602,782 $MTCO_2e$ and 18,678,372 $MTCO_2e$, respectively)[11]
- Annual GHG reductions in 2050: 48,858,287 $MTCO_2e$ (19% reduction in energy consumption emissions and 7% reduction in energy production emissions from 2005 levels 262,602,782 $MTCO_2e$ and 18,678,372 $MTCO_2e$, respectively)

GHG reductions and cost per ton of GHG reduced (a measure of cost-effectiveness), by strategy and individual action, are presented in Figure 10 and Table 6 below.

Figure 10. Annual GHG Reductions from BAU Through 2050 for Energy Production Strategies and Actions ($MMTCO_2e$)



[11] Emission reductions from strategies that affect the electricity generation fuel mix (e.g., utility scale renewable generation, nuclear generation, cap and trade) are accounted for in the energy consumption sector based on the reduction in the electricity consumption emission factor (i.e., a reduction of carbon intensity of the grid). Distributed renewable electricity generation is also accounted for as reductions to energy consumption emissions. Thus, emissions from these strategies are compared to the BAU emissions from energy consumption. Emissions reductions from coal mine methane capture and upstream oil and natural gas are accounted for in the energy production sector, so these are compared to the BAU emissions from energy production.

Table 6. Annual GHG Reductions in 2025 and 2050 and Cost per Ton of GHGs Reduced for Energy Production Strategies and Actions

Strategies and Actions Included in Higher-Level Strategy Quantitative Modeling	Annual GHG Reductions in 2025 ($MTCO_2e$)	Annual GHG Reductions in 2050 ($MTCO_2e$)	Cost per Ton of GHG Reduced ($/ton of CO2e)
Increase use of clean, distributed electricity generation resources	**544,502**	**-1,512,918**	**NA[a]**
Invest in and promote building-scale solar	NA[a]	48,210	-$285
Incentivize and increase use of combined heat and power	544,502	-1,561,128	NA[b]
Create a diverse portfolio of clean, utility-scale electricity generation	**30,015,060**	**48,792,751**	**$29**
Increase Alternative Energy Portfolio Standard (AEPS) Tier 1 targets, and further increase in-state generation and use of renewables	6,703,719	27,639,941	$27
Implement policy to maintain nuclear generation at current levels	18,412,115	21,152,811	$26
Limit carbon emissions through an electricity sector cap and trade program	4,899,227	NA[c]	$55
Reduce impacts of fossil fuel energy production and distribution	**104,879**	**29,598**	**$19**
Implement policies and practices to reduce methane emissions across oil and natural gas systems	104,879	29,598	$19
Increase production and use of alternative fuels	**1,673,531**	**2,796,683**	**-$20**
Increase recovery and use of gas from coal mines, agriculture, wastewater, and landfills for energy	1,673,531	2,796,683	-$20

[a] *There is sufficient building scale solar in 2025 in the BAU to meet the 6% solar carve out assuming 90% is utility scale and 10% is building scale, so there are no GHG reductions from BAU in 2025. The modeling projects non-zero savings starting in 2026.*

[b] *Because this action (CHP) is projected to result in a net increase in GHG emissions by 2050 when using an average emission factor to calculate GHG reductions, a reduction cost per ton is not an applicable metric as it does not allow for a consistent comparison of costs per ton across the various strategies and actions. GHG emissions reduced through electricity savings are counter-balanced by GHG emissions resulting from increased natural gas use. However, when looking at emission reductions based on marginal emission factors, GHG reductions from CHP are positive across the entire time series through 2050, although they taper significantly at the end of the time series. Further information is contained in the CHP Analysis Discussion on page 71. Note: the analysis looked at the impacts from new natural gas combustion in new CHP systems and did not quantify the potential from using bottoming cycle CHP to capture waste heat from existing combustion systems, which was beyond the scope of this analysis.*

[c] *The GHG emission reductions from expanding AEPS requirements and maintaining nuclear generation are projected in this modeling analysis to meet the cap in 2050 without a cap and trade program.*

Increase Use of Clean, Distributed Electricity Generation Resources

Clean, distributed electricity generation refers to renewable energy, such as solar and wind, that generate electricity on-site where it is used. These systems reduce reliance on fossil fuels and provide climate resilience benefits, including reduced reliance on centralized power. They also offer the opportunity to save money on electricity costs by installing on-site renewable energy and also reduce power lost through transmission and distribution.

Leadership Actions

State and local governments can support the use of clean, distributed electricity through incentives and policy. For example, governments can:

- **Invest in and promote building-scale solar energy.**

  Separate efforts from DEP through the *Finding Pennsylvania's Solar Future Plan* (PA DEP 2018b) have specifically focused on outlining steps Pennsylvania needs to take to advance the use of solar in the commonwealth. Distributed solar PV strategies to be undertaken include:

  - Give customer-generators the opportunity to use virtual net metering
  - Identify and remove the barriers to the deployment of community solar systems in Pennsylvania
  - Ensure alternative ratemaking is addressed in a manner that does not create a disincentive for solar deployment
  - Encourage municipalities to offer PACE programs
  - Accelerate use of smart inverters to manage over-voltage concerns on low voltage distribution lines and avoid unnecessarily adding costs on small solar distributed generation projects

  Steps for implementing these strategies, and examples of where they have been successfully implemented in other jurisdictions are outlined in the *Finding Pennsylvania's Solar Future Plan* (PA DEP 2018b).

- **Incentivize and increase use of combined heat and power (CHP)** for large campuses, hospitals, infrastructure, mass transit, and industry (e.g., through streamlining and best-practices sharing).

  In April 2018 the Pennsylvania Public Utility Commission (PUC) adopted a policy statement geared toward helping advance the development of CHP technology (http://www.puc.state.pa.us/utility_industry/natural_gas/chp_cogeneration.aspx). The PUC has since been focusing research and efforts to examine the viability of increased implementation of CHP through research and consultation with industry experts, including those from the private sector and DOE, among others. It is expected that the PUC (through its CHP Working Group) will determine what policies will make CHP more accessible to interested parties while balancing the needs and interests of all stakeholders. One issue that has already been identified by the PUC through their CHP workgroup is standby rates as an impediment to CHP–which would need to

be addressed by the PUC. This active work will be critical to help pave the way for increased CHP use in Pennsylvania.

The above actions in **bold** are reflected in the quantified key metrics below. Other actions leaders can take include:

- Support community solar legislation and develop model local ordinances (e.g., to streamline community solar development), potentially utilizing the "Zoning and Permitting Solar in Your Municipality" guidebook (https://www.pennfuture.org/Files/Admin/SunSHOT_Guide.compressed.pdf).

CHP Analysis Discussion

To be able to look at emission reductions, and therefore cost per ton of CO2 reduced, consistently across all mitigation strategies, this Climate Action Plan uses an average grid electricity emission factor to calculate these reductions. However, US EPA Guidance (see: https://www.epa.gov/sites/production/files/2015-07/documents/fuel_and_carbon_dioxide_emissions_savings_calculation_methodology_for_combined_heat_and_power_systems.pdf) advises use of marginal emission factors when calculating GHG reductions as a result of the use of CHP. Average and marginal emission factors differ in that:

- An **average grid emission factor** does not take into account the order in which power generation units are dispatched to meet demand, but instead calculates an annual average that relies on the amount of each resource (e.g., coal, wind, solar) used to generate power and how much power each of those resources generates over the annual time period.
- A **marginal emission factor** takes into account the fact that specific electric generating units operating on the "margin" of grid dispatch operations. Typically, in the PJM system, certain "must run" units are dispatched first so that they operate at full capacity, then intermediate fossil fuel generation is dispatched, with fossil peaking generation dispatched last. Must-run units in PJM include nuclear and utility-scale renewable sources, which are carbon-free sources of power. Since nuclear and renewable generation are must-run sources, they will not actually be shut off or modulated when electric demand decreases. According to EPA guidance these sources should not be included in the emission factor used to calculate emissions reductions from CHP. The guidance recommends a marginal generation emission factor be used to calculate emission reductions from CHP use as opposed to an average grid emission factor, where the marginal emission factor can be proxied by using the emission factor that takes into account only fossil fuel power generation.

The analysis team calculated and applied a marginal emission factor versus the average emission factor, and the results of this calculation and the comparison are presented in the table below.

Total GHG Emission Reductions (MTCO2e)	2020	2025	2030	2050
Marginal Emission Factor	**446,084**	**2,320,883**	**2,691,211**	**658,466**
Average Emission Factor	**158,331**	**544,502**	**(4,207)**	**(1,561,128)**
New CHP Electricity Generated (GWh) ***(in addition to current installations)***	1,067	7,855	14,811	17,618

As seen in this table, calculations using the average emission factor result in a net increase in GHG emissions later in the time series (with the switch from a net decrease in annual GHG emissions to a net increase in 2030), whereas when using the marginal emission factor GHG emission reductions result in a net decrease through the entire time series. The switch from coal to natural gas for PJM's fossil fuel mix results in less significant reductions, but CHP is expected to continue producing net emission reductions through 2050 when using marginal emission factors. Therefore, despite the fact that its GHG reductions decrease over time as the grid's GHG emissions intensity falls, and also taking into account the reliability and resiliency benefits CHP offers, it remains an important and viable mitigation option for the commonwealth.

Long-term contributions of CHP to GHG emission reductions is a continually evolving research and analysis area, given that more ambitious renewable generation targets are being set and high-efficiency natural gas combined cycle generation continues to increase as a fraction of the generation mix. This is an area worth more detailed study and investigation.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

The climate resilience benefits of clean, distributed electricity production include:

- Increase reliability of power grids by providing more generation sources with more diverse contributions to generation capacity, the ability to reduce transmission congestion, and reduced risk of outages.
- Increased energy reliability for key facilities and microgrids during extreme events by planning for and providing least impact backup power supply on-site, reducing operational or security disruptions.

Environmental Benefits & Costs

In addition to its measured benefits and cost, clean, distributed energy can have other environmental benefits, including reduced strain on water resources, and reduced thermal pollution from powerplant cooling water. Such strategies can also reduce the environmental effects associated with fuel extraction and transportation.

Economic Benefits & Costs

In addition to the macroeconomic benefits quantified in this report, clean distributed energy investments can create social equity benefits to the extent that resources are developed as greater total numbers of projects, distributed across a greater total number of jurisdictions. This can bring economic benefits to more Pennsylvania communities. Additionally, Pennsylvania citizens and businesses can save money on electricity costs by installing on-site renewable energy and also reduce power lost through transmission and distribution.

Key Metrics

Net Present Value: $7,785 Million[a]

Cost-per-ton of GHG Reduced: NA[b]

	2025	2050		2025	2050
	GWh Electricity Consumption Reduced			***BBtu Nat. Gas Consumption Increased[e]***	
	7,855	17,861		42,448	95,191
	GWh Renewable Electricity Generation Increased				
	0	243			
	$MTCO_2e$ GHG Emissions Reduced[c]			***MT Air Pollutant Emissions Reduced[c]***	
	544,502	-1,512,918	NO_x	619	-1,848
			SO_2	5,695	6,256
			Hg	0.10	0.08

	2025	2050		2025	2050
	Capital Expenditures ($ Million)			***Maintenance & Repair Costs ($ Million)***	
	$327	-$2		$104	$233
	Number of Jobs Supported			***Increase in GSP ($ Million)***	
	3,609	15,126		$22	$712
	Increase in Disposable Personal Income Per Household ($/Household)			***Energy Expenditure Savings ($Million)[d]***	
	$20	$178		$578	$1,217

[a] Net Present Value for this strategy includes capital expenditures, energy savings, fuel subsidies, and maintenance and repair costs.

[b] Because this action (CHP) is projected to result in a net increase in GHG emissions by 2050 when using an average emission factor to calculate GHG reductions, a reduction cost per ton is not an applicable metric as it does not allow for a consistent comparison of costs per ton across the various strategies and actions. GHG emissions reduced through electricity savings are counter-balanced by GHG emissions resulting from increased natural gas use. However, when looking at emission reductions based on marginal emission factors, GHG reductions from CHP are positive across the entire time series through 2050, although they taper significantly at the end of the time series. In this modeling analysis, that point occurs during the 2040s. Note: the team looked at the impacts from new natural gas combustion in new CHP systems and did not quantify the potential from using bottoming cycle CHP to capture waste heat from existing combustion systems, which was beyond the scope of this analysis.

[c] Negative "reductions" indicate increases from BAU.

[d] Energy Expenditure Savings in this strategy represent energy bill savings on natural gas and electricity.

[e] Btus from natural gas consumption is in addition to that used for electricity generation.

Key Analysis Assumptions:

- *Quantified metrics reflect the policies, programs, and actions in* **bold** *above.*
- *Building-scale solar is 10 percent of total solar development, as outlined in the Finding Pennsylvania's Solar Future Plan (PA DEP 2018b) Scenario B, and building-scale solar capacity is split evenly between residential and commercial.*
- *Efficient combined heat and power (CHP) systems are assumed to receive a preferential retail natural gas rate of $5 per MMBtu, escalating according to BAU natural gas growth rates through 2050. ICF's proprietary Combined Heat and Power Database is used to identify potential CHP sites; all CHP high load factor sites are assumed to have economic potential.*

Other Key Performance Indicators

In addition to the metrics listed above, example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Installed capacity
- Production as share of sector consumption and production
- kW of installed renewable energy
- Investments made in renewable energy
- Alternative Energy Credits earned or awarded

What You Can Do to Increase Use of Clean, Distributed Electricity Generation Resources

Pennsylvania citizens can support this strategy by taking the following actions:

- Invest in rooftop solar electric and water heating systems on your home.

What Businesses Can Do to Increase Use of Clean, Distributed Electricity Generation Resources

Pennsylvania businesses can support this strategy by taking the following actions:

- Install on-site renewable energy generation and take the necessary steps to sell the AECs into the AEPS market.
- Implement combined heat and power at appropriate facilities.

Create a Diverse Portfolio of Clean, Utility-Scale Electricity Generation

A diverse and clean electricity grid that relies on a mix of fuels makes the most of Pennsylvania's energy resources. Reducing the overall carbon intensity of the electricity generated in Pennsylvania affects every electricity grid customer in the commonwealth, making it one of the most critical strategies for reducing GHG emissions, particularly as the transportation sector begins to increase its reliance on electricity.

Leadership Actions

The Commonwealth of Pennsylvania can advance this strategy by pursuing a selection of the following policies, programs, and actions:

- **Increase Alterative Energy Portfolio Standard (AEPS) Tier 1 targets, and further increase in-state generation and use of renewables** (utility-scale solar), if possible, through actions in line with Pennsylvania's Solar Future Plan through 2030.[12,13]

  The existing AEPS in Pennsylvania was established in 2004 and requires that electric distribution companies and electric generation suppliers ensure that by 2021 a minimum of 18% of total electric supply is from qualified alternative energy resources. This is being achieved through a mix of resources, including solar PV, wind, low impact hydro, waste coal, etc. This action focuses on expanding the AEPS, both in terms of its total percentage requirements, and in terms of the more specific tiered requirements by resource type.

[12] To strengthen the AEPS over time, a periodic review process with an eye toward further strengthening the goals as technology allows could be used.
[13] Increasing the AEPS will also further incentivize DG as well as utility-scale electricity generation.

- **Implement policy to maintain nuclear generation at current levels**.

  Two large nuclear power plants could go offline in Pennsylvania in the next few years due to competitive economic market conditions. Three Mile Island and Beaver Valley are expected to close for financial reasons in 2019 and 2021, respectively, as their owners have stated that low wholesale market prices have made them uneconomic. Keeping these plants online would both save jobs (approximately 1,500 jobs between both plants) and ensure zero emissions sources of baseload electricity are maintained in the commonwealth. Given how quickly the expected closures are approaching, the Pennsylvania legislature would need to act swiftly to implement this action. This is a problem that has been faced in other states such as New York (Spector 2018), New Jersey, Illinois, New York, and Wisconsin. It could be solved through a number of options that the Pennsylvania legislature could consider, including:

  - Establishing a Zero Emissions Credit (ZEC) program (done in New Jersey, Illinois and New York) where generators get paid per MWH of zero emissions electricity generated at their facility. To create this mechanism, the legislature would need to enact legislation that sets the price, timeframe, and other details of the credit mechanism, or directs a state agency to so do. Other states have placed time limits on the credits and defined other key details such as adjusting the value of the ZECs over time based on specific indicators.
  - Incorporating nuclear in the AEPS. The legislature could create a new and separate tier for nuclear power within the AEPS structure. It would define a specific percentage of electricity sales that electric distribution companies would have to purchase from Pennsylvania nuclear plants. Another approach would be to add nuclear to an existing AEPS resource tier, with a specific "carve-out" for nuclear, similar to the current solar carve-out. In this latter approach, the total tier resource requirement would need to be increased by at least the amount of the nuclear carve-out. If all of the nuclear generation in the state were maintained, nuclear would comprise ~35% of total generation in 2030 in and ~30% in 2050.

  These options and what has worked in various states are described further in the National Conference of State Legislature's report *State Options to Keep Nuclear in the Energy Mix:* http://www.ncsl.org/Portals/1/Documents/energy/StateOptions_NuclearPower_f02_WEB.pdf.

  Maintaining the current nuclear generation levels in Pennsylvania would ensure that 18,412,115 MTCO2e of GHG emissions are reduced in 2025 and 21,152,811 MTCO2e of GHG emissions are reduced in 2050.

- **Limit carbon emissions through an electricity sector cap and trade program**.

  To implement this action, the state legislature could enact legislation, or the Governor could explore a regulation under the Air Pollution Control Act that authorizes the state to establish a state-wide emissions trading program that addresses the electricity sector. DEP could promulgate a rulemaking to establish the framework and auction participation rules and requirements.

Many other states have already gone through this effort in the Northeast and other parts of the country, and America's Pledge *America's Low-Carbon Future: A "Bottom-Up" Opportunity Action Agenda for Climate Action in the United States* (America's Pledge 2018a) outlined state coalitions for carbon pricing as one of their top ten action areas for states to act on climate change. In creating the rules for the cap and trade program, lawmakers and DEP could look at what other states have done as models, including Virginia and New Jersey (see https://www.deq.virginia.gov/Programs/Air/GreenhouseGasPlan.aspx and https://www.state.nj.us/dep/aqes/rggi.html). This recommendation is also consistent with Proposed Strategy 4 of the *Finding Pennsylvania's Solar Future Plan* (PA DEP 2018).

This Plan models a cap and trade program that requires a carbon cap equal to a 30 percent reduction from 2020 CO_2 emissions levels by 2030. DEP could promulgate rules for the cap and trade program, establish roles and responsibilities for the program (e.g., for the auction of allowances). If Pennsylvania joined an existing program, such as the Regional Greenhouse Gas Initiative (RGGI), many of these details would already be addressed, including the actual auctioning of allowances. The GHG emission reductions from expanding AEPS requirements and maintaining nuclear generation are projected in this modeling analysis to meet the modeled emissions cap in 2050 without a cap and trade program.

The above actions in **bold** are reflected in the quantified key metrics below. Other actions leaders can take include:

- Establish a workgroup to help optimize siting of renewables, and to review and streamline permitting and regulations at the state and local levels (e.g., to address high value implementable actions and technologies such as community choice aggregation and battery storage).

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

Create a diverse portfolio of clean, utility-scale electricity generation can:

- Reduce power outages due to extreme events.
- Reduce dependency on single fuels and sensitivity to price changes.

Environmental Benefits & Costs

In addition to the GHG and criteria air pollution metrics quantified above, clean utility-scale generation can reduce water use for powerplant cooling as well as environmental effects of fuel extraction and transportation. Some clean power technologies have their own environmental effects, such as wind power's potential impacts to birds and bats, or the embodied effects of materials used in manufacturing certain technologies.

Economic Benefits & Costs

Clean energy supply technologies already employ about 13,000 people in Pennsylvania, including renewable energy, grid modernization, and related businesses (E2 2018); the employment effects modeled in the 2018 Plan update already assume these jobs are in place.

Key Metrics

Net Present Value: -$33,188 Million[a]

Cost-per-ton of GHG Reduced: $29/$MTCO_2e$[b]

	2025	2050		2025	2050
	GWh Renewable Energy Generation Increased			***MW Renewable Energy Capacity Increased***	
	13,867	58,725		6,496	24,486
	$MTCO_2e$ GHG Emissions Reduced[c]			***MT Air Pollutant Emissions Reduced***	
	30,015,060	48,792,751	NO_x	31,987	58,821
			SO_2	58,317	112,542
			Hg	1.32	2.45
	Capital Expenditures ($ Million)			***Maintenance & Repair Costs ($ Million)***	
	$1,949	$1,127		$691	$1,293
	Number of Jobs Supported			***Decrease in GSP ($ Million)***	
	-2,493	-6,205		$261	$187
	Energy Expenditure Savings ($Million)[d]			***Decrease in Disposable Personal Income Per Household ($/Household)***	
	-$31	$1,825		$24	$68

[a] *Net Present Value for this strategy includes capital expenditures, energy savings, and maintenance and repair costs*

[b] *A negative "cost-per-ton" indicates cost savings*

[c] *This represents the GHG emission reductions counted toward meeting Pennsylvania's GHG emission reduction target (i.e., those associated with electricity that is consumed within the commonwealth and not those associated with electricity that is exported).*

[d] *Energy Expenditure Savings in this strategy represent savings on fuels purchased for electricity generation at the utility scale.*

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU. Negative cost-per-ton represents net cost savings.

Key Analysis Assumptions:

- *Quantified metrics reflect the policies, programs, and action in* **bold** *above.*
- *The AEPS requirements will increase from eight percent Tier I renewables by 2020 (2020-2021 year) to 30 percent Tier 1 by 2030 and 50 percent by 2050 with a six percent solar carve out phased in linearly to 2030. The six percent solar carve out is in line with the Finding Pennsylvania's Solar Future Plan (PA DEP 2018b).*
- *While Beaver Valley and Three Mile Island nuclear plants will close in 2021 and 2019 respectively in the BAU Scenario, these plants will be brought back online or kept open as part of this strategy and all other levels of nuclear generation in Pennsylvania will remain constant through 2050. Prices used in this analysis*

represent what would be needed to maintain the existing nuclear capacity. For modeling purposes, the analysis team used a zero emissions credit value ranging over the time series from about $7.50 to $12 per MWh.

- *A carbon emission limit for each year is established, using a 30 percent reduction from 2020 CO_2 levels by 2030. The post-2030 emission cap that is modeled leads to a phase out of most remaining higher carbon emitting sources of generation other than waste coal by 2050. The carbon emissions limit in each year is first met through the expansion of the AEPS and nuclear generation and then by ramping up natural gas generation and displacing higher carbon emitting sources of generation, then by reducing these generation sources further through a reduction in exports.*
- *For the cap and trade program carbon prices are designed to achieve the cap selected for modeling purposes (see above); the carbon price is high enough to reduce the cost-competitiveness of higher carbon emissions sources relative to natural gas, which is the incremental step beyond the AEPS that is needed to meet carbon limits and overall GHG reduction targets used for this modeling exercise.*

Other Key Performance Indicators

In addition to the metrics listed above, example indicators that Pennsylvania could use to measure progress toward this strategy include:

- AECs generated or purchased
- Compliance with the AEPS
- Generation levels from specific low-emission sources
- Carbon intensity of the electricity grid
- Number of communities or businesses using community choice aggregation

What You Can Do to Create a Diverse Portfolio of Clean, Utility-Scale Electricity Generation

Pennsylvania citizens can support this strategy by taking the following actions:

- ► Purchase clean power through PA Power Switch and promote the opportunity to others.

What Businesses Can Do to Create a Diverse Portfolio of Clean, Utility-Scale Electricity Generation

In addition, Pennsylvania businesses can support this strategy by taking the following actions:

- ► Collaborate with utilities, regulators, customers, and power suppliers to develop clean energy resources while maintaining grid safety and reliability.
- ► Support community choice aggregation.
- ► Support financing strategies for clean energy sources.
- ► Develop on-site clean energy resources.
- ► Choose to buy clean power through competitive electricity markets.
- ► Enter into power purchase agreements for clean power.

Reduce Impacts of Fossil Fuel Energy Production and Distribution

The fossil fuel industry has historically been, and continues to be, one of the largest economic drivers in Pennsylvania. The recent rise in natural gas production from the Marcellus and Utica Shale formations has reaffirmed the importance of fossil fuels to Pennsylvania's economy. However, oil and natural gas production pose several environmental, health, and safety risks, including the release of methane to the atmosphere throughout the production, transmission, storage, and distribution processes. There are many cost-effective operational changes and technologies for reducing methane emissions in these processes that could be deployed to improve the industry's overall net benefits by reducing one of its larger environmental costs.

Leadership Actions

The Commonwealth of Pennsylvania can advance this strategy by:

- **Implementing policies and practices to reduce methane emissions across oil and natural gas systems** (e.g., from well heads, abandoned wells, leakage in distribution systems). These policies and practices are reflected in the quantified key metrics below.

Pennsylvania has a long history of being one of the largest fossil fuel producers in the country and is therefore at the forefront of state action for reducing methane emissions from the oil and natural gas sector. These reductions can be achieved through both mandatory and voluntary reductions, an approach which has proven to be effective in the past. Pennsylvania has made progress on a number of initiatives to reduce methane emissions from the oil and natural gas sector, which will go a long way to helping achieve this action. Governor Tom Wolf launched a Methane Reduction Strategy (https://www.dep.pa.gov/Business/Air/Pages/Methane-Reduction-Strategy.aspx) designed to reduce emissions from natural gas well sites, compressor stations and along pipelines and protect the environment, reduce GHG emissions, and help businesses reduce the waste of a valuable product. To help achieve this goal, DEP finalized the revised general permits (GP) GP-5 for Natural Gas Compression Stations, Processing Plants, and Transmission Stations; (DEP 2018d) and new GP-5A for Unconventional Natural Gas Well Site Operations and Remote Pigging Stations; (DEP 2018e) as well as related technical resources for operators. In addition to the action already being taken, DEP could set a regular schedule for GP review and updates to continue to further drive reductions, including the removal of exemptions for certain types of facilities. DEP also encourages in-state producers to participate in voluntary programs like the EPA Natural Gas STAR Program to help to further drive reductions.

Additionally, steps outlined in the 2015 Climate Action Plan continue to be relevant for this strategy (PA DEP 2015), including:

- Expand verification of methane emission data reported to DEP by operators.
- Continue to investigate and quantify methane emissions from plugged and abandoned wells, including wells plugged by DEP, through partnerships between DEP, academia, and citizen-science groups.
- Expand the use of remote-sensing technologies to identify fugitive and non-fugitive emission sources throughout the present and historical areas of operating, abandoned, and plugged oil

and natural gas wells. This may include vehicle or aircraft-mounted methane detection equipment, as well as hand-held methane detection equipment, such as FLIR cameras.

- As a result of these surveys and results, develop a source emissions inventory and recommendations for developing and enhancing programs to minimize and eliminate methane emissions, expanding on what DEP already includes in the state GHG inventory.

Strategy Benefits and Costs

Environmental Benefits & Costs

In addition to the metrics quantified in this report, reducing upstream effects of fossil fuel production can create additional environmental benefits. To the extent that increasing the focus on "cleaner" upstream practices improves overall industry performance, such strategies could reduce the risks of groundwater and surface water contamination, the health risks associated with methane and other hydrocarbon emissions in nearby communities, and the safety risks associated with combustible fuels and byproducts.

Reducing methane emissions will also have other environmental benefits such as reducing the formation of ozone by reducing emissions of volatile organic compound emissions, local air pollutants, and odors, all of which have negative effects human health (e.g., in the form of smog) and ecosystems (EPA 2016c).

Economic Benefits & Costs

The metrics below constitute the relevant benefits and costs related to this strategy.

Key Metrics

Net Present Value: -$59 Million[a]

Cost-per-ton of GHG Reduced: $19/$MTCO_2e$

	2025	2050		2025	2050
	$MTCO_2e$ GHG Emissions Reduced				
	104,879	29,598			
	Capital Expenditures ($ Million)			***Maintenance & Repair Costs ($ Million)***	
	$2.51	$5.49		$0.52	$1.23
	Number of Jobs Supported			***Impact on GSP ($ Million)***	
	13	-13		$0.00	-$1.70
	Decrease in Disposable Personal Income Per Household ($/Household)				
	$0.08	$0.34			

[a] Net Present Value for this strategy includes capital expenditures, revenues from recovered natural gas, and maintenance and repair costs.

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU. Negative cost-per-ton represents net cost savings.

Key Analysis Assumptions:

- *Quantified metrics reflect the policies, programs, and action in* **bold** *above.*
- *Emission reductions are for both conventional and unconventional sources and consider regulatory drivers at the federal-level (New Source Performance Standards, in BAU) and state-level (current Exemption 38(c) control standards to existing sources starting in 2020 and General Permit 5-A).*
- *Activity and emissions rely on the U.S. EIA AEO (EIA 2018), internal calculations and data from DEP, and an Environmental Defense Fund Tool for Evaluating Options for Reducing Methane Emissions in Pennsylvania.*

Other Key Performance Indicators

In addition to the metrics listed above, example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Volatile Organic Compound (VOC) emissions
- Instances of water contamination in proximity to natural gas or oil production systems

What You Can Do to Reduce Impacts of Fossil Fuel Energy Production and Distribution

Pennsylvania citizens can support this strategy by taking the following actions:

- ► Support public policies to reduce impacts that damage the environment and health.

What Businesses Can Do to Reduce Impacts of Fossil Fuel Energy Production and Distribution

Pennsylvania **coal, oil and natural gas businesses** can support this strategy by taking the following actions:

- ► Join the EPA Natural Gas STAR program to benefit from public recognition, information sharing, and peer networking by transparently reporting voluntary methane emissions reductions activities.
- ► Invest in methane leak detection to reduce emissions and safety hazards.
- ► Update control technology and implement best management practices to control methane emissions at well sites, in addition to properly plugging abandoned wells.
- ► Join the Center for Responsible Shale Development.
- ► Recover 10% of total methane emissions from coal mining through various technologies and techniques before, during, and after extraction.

Increase Production and Use of Alternative Fuels

Alternative fuels are a critical aspect of the AEPS in Pennsylvania and are also currently incentivized or mandated in the transportation sector through the AFIG program and Act 78 which requires that 2 percent of in-state diesel fuel production be biodiesel. There are a number of facilities already active in Pennsylvania that are producing alternative fuels or using them to generate electricity or energy, but there is opportunity for further development.

Leadership Actions

The Commonwealth of Pennsylvania can promote the production and use of alternative fuels by pursuing policies, programs, and actions, such as the following:

- **Increase recovery and use of gas from coal mines, agriculture, wastewater, and landfills for energy.**

  Multiple national voluntary programs run by the U.S. EPA including the Landfill Methane Outreach Program, the Coalbed Methane Outreach Program, Ag Star, and the Global Methane Initiative offer industry the technical assistance needed to implement methane recovery and reuse for energy projects. These programs also provide recognition and other incentives (e.g., grants and cooperative agreements) for voluntary action and involvement. DEP could expand outreach efforts to help broaden participation in these effective programs to increase the development and use of alternative energy projects in Pennsylvania.

  Additional recent action within Pennsylvania to make general permits amenable and streamlined for the beneficial use of landfill gas (LFG) (e.g., GP-26; reciprocating engines using LFG) and other energy uses of recovered gas (e.g., Waste Management General Permit WMGM042 for using food waste in anaerobic digester) can be built upon to continue to encourage and expand the use of alternative energy projects.

  Similarly, Pennsylvania, through its various economic development arms, should encourage co-locating industrial and institutional facilities and commercial business centers to facilitate the utilization of waste heat from landfill-gas-to-energy projects and waste-to-energy facilities. Such efforts would offset consumption of fossil fuels and would also provide additional revenue to these facilities. Generally, the focus should be on promoting co-development at waste-to-energy facilities, which have higher waste heat loads and more centrally located facilities.

The above action in **bold** is reflected in the quantified key metrics below. Other actions leaders can take include:

- Increase sustainable biofuel production in Pennsylvania (e.g., expand on biodiesel requirements outlined in Pennsylvania Act 78 of 2008).
- Finalize the draft Bureau of Air Quality general permit for reciprocating engines using LFG, which incentivizes increased beneficial use of landfill gas, and reduces downtime due to maintenance at existing projects.
- Continue to support the sustainable harvest and use of biomass feedstocks for thermal energy through initiatives such as PA Fuels for Schools and Communities (see http://www.pafuelsforschools.psu.edu/about/default.asp). These systems often displace fuel oil, particularly where natural gas is not available, and support the local economy.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

Increasing the production and use of alternative fuels can:

- Reduce sensitivity to fuel price shocks or fuel scarcity.
- Keep facilities with on-site fuel production or storage operational during extreme events.

Environmental Benefits & Costs

Using alternative fuels, such as landfill gas, to produce electricity not only burns methane that could be released to the atmosphere, it also destroys most hazardous air pollutants and VOCs that are present in landfill gas. This reduces health risks and risks to the ecosystem.

Economic Benefits & Costs

The alternative fuels industry already employs about 1,400 people in Pennsylvania (E2 2018); the employments effects modeled in the 2018 Plan update are additional to this base.

Key Metrics

Net Present Value: $1,504 Million[a]

Cost-per-ton of GHG Reduced: - $20/$MTCO_2e$[b]

	2025	2050		2025	2050
	GWh Electricity Consumption Reduced			***GWh Renewable Electricity Generation Increased***	
	331	876		331	876
	BBtu Nat. Gas Consumption Reduced			***BBtu Biogas Consumption Increased***	
	1,413	3,772		3,598	9,522
	$MTCO_2e$ GHG Emissions Reduced			***MT Air Pollutants Emissions Reduced[c]***	
	1,673,531	2,796,683	NO_x	-797	-2,230
			SO_2	197	193
	Capital Expenditures ($ Million)			***Maintenance & Repair Costs ($ Million)***	
	$37	$0.24		$9	$20
	Number of Jobs Supported			***Increase in GSP ($ Million)***	
	230	4,018		$14	$129
	Energy Expenditure Savings ($Million)[d]			***Increase in Disposable Personal Income Per Household ($/Household)***	
	$45	$132		$0.00	$0.04

[a] *Net Present Value for this strategy includes capital expenditures, energy savings, revenues, and maintenance and repair costs.*

[b] *Negative cost-per-ton indicates cost savings.*

[c] Emission factors for Hg emissions from biogas consumption were not readily available. Negative reductions indicate an increase compared to BAU.
[d] Energy Expenditure Savings in this strategy represent energy bill savings on natural gas and electricity as well as revenues from selling electricity produced from landfill gas and captured coal mine methane.
Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU. Negative cost-per-ton represents net cost savings.

Key Analysis Assumptions:

- *Quantified metrics reflect the policies, programs, and action in* **bold** *above.*
- *For coal mine methane, full economic potential, estimated in the draft Pennsylvania Energy Assessment Report prepared in 2018, is realized each year through 2050 and then emission reductions are calculated with the Coal Module from EPA's SIT.*
- *Agriculture Waste, Landfill Gas, and Wastewater methane use is expected to increase based on information in ICF's CHP Database and considers support of the expanded AEPS through 2050 (see above).*

Other Key Performance Indicators

In addition to the metrics listed above, example indicators that Pennsylvania could use to measure progress toward this strategy include:

- VOC emissions
- Hazardous air pollutant emissions
- Number of alternative energy projects in Pennsylvania
- Volume of biofuel production in Pennsylvania

What You Can Do to Increase Production and Use of Alternative Fuels

Pennsylvania citizens can support this strategy by taking the following actions:

- ► Purchase "flex-fuel" labeled vehicles, which can burn E85 fuel.
- ► Advocate for greater alternative fuel infrastructure, including the development and use of renewable natural gas (biogas cleaned up and injected in the pipelines).
- ► Convert personal vehicle to be capable of operating on alternative fuels.
- ► Refuel your diesel vehicle with biodiesel containing higher bio-content.

What Businesses Can Do to Increase Production and Use of Alternative Fuels

Pennsylvania businesses can support this strategy by taking the following actions:

- ► Take advantage of Pennsylvania's AFIG program to purchase or convert business vehicle fleet to be capable of burning biofuels or compressed natural gas (CNG) or other alternative fuels.
- ► Capture methane emissions and convert to energy through electricity generation or high-BTU projects, which process landfill gas into pipeline quality natural gas, and may qualify for federal RINs under the Federal Renewable Fuel Standard.

Agriculture

According to the Census of Agriculture, there are nearly 60,000 farms and ranches on more than 7.7 million acres of land in Pennsylvania (USDA 2012). In fact, 27% of all land use in Pennsylvania represents agricultural land.

Agriculture is a major driver of the state's economy, accounting for approximately $83.8 billion in direct economic output, including $22.8 billion in value-add (PDA 2018). This industry generates approximately $135.7 billion in total economic impact each year and supports 579,000 jobs with $26.9 billion in earnings (PDA 2018).

Pennsylvania ranks number one in the nation for mushroom production, growing over half of the mushrooms in the United States and providing nearly $530 million in sales a year (Whetstone 2014). The state is also a leader in export grade hardwood. Other unique crops where Pennsylvania ranks among the top 5 producers in the nation include poultry egg-layers, milk from cows, Christmas trees, and the nursery, greenhouse, floriculture, and sod sectors (PDA 2018). Conventional commodities such as corn, soybeans, and wheat are also commonly grown in the state.

Specific areas that affect emissions in this sector include enteric fermentation, manure management, and agricultural soil management as well as fuel combustion emissions.

Climate Change Impacts

Overall, climate change will alter growing conditions and growing seasons for agriculture. The exact effects on specific crops are uncertain, but the overall expected impacts of climate change on agriculture in Pennsylvania (Shortle et al. 2015) include:

- Changes in agricultural productivity and profitability or shifts in ideal crop ranges that could require farmers to adjust practices (e.g., irrigation, fertilization) or switch to new crops. Example agricultural products that could be affected include dairy, due to less production from heat stress, and field crops.
- Indirect effects on food prices, increasing financial risks for farmers and citizens.

Opportunities to Reduce Emissions and Adapt to Climate Change

In the Agriculture sector, the analysis team has identified two main strategies to reduce emissions and adapt to climate impacts:

- **Use agricultural best practices**
- **Provide resources and technical assistance to farmers to adapt**

Each strategy description below includes leadership, citizen, and business actions that support the strategy; a summary of strategy benefits and costs; and key performance indicators.

In addition, these Agriculture strategies include one action (no-till farming) that the team quantitatively analyzed (see Table 7 below). This action is expected to result in:

- Annual GHG reductions in 2025: **208,331 $MTCO_2e$** (3% reduction from 2005 levels of 7,566,296 $MTCO_2e$)[14]
- Annual GHG reductions in 2050: **328,070 $MTCO_2e$** (4% reduction from 2005 levels of 7,566,296 $MTCO_2e$)

GHG reductions and cost per ton of GHG reduced (a measure of cost-effectiveness) are presented in Figure 11 and Table 7 below.

Figure 11. Annual GHG Reductions from BAU Through 2050 for Agriculture Strategies and Actions ($MMTCO_2e$)

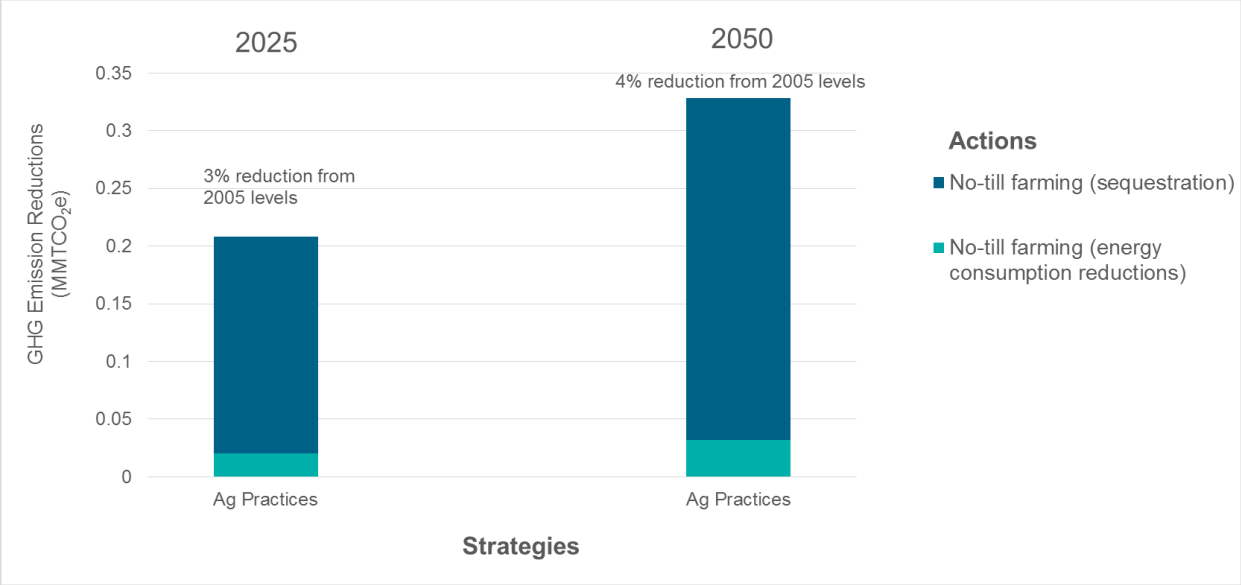


Table 7. Annual GHG Reductions in 2025 and 2050 and Cost per Ton of GHGs Reduced for Agriculture Strategies and Actions

Strategies and Actions Included in Higher-Level Strategy Quantitative Modeling	Annual GHG Reductions in 2025 ($MTCO_2e$)	Annual GHG Reductions in 2050 ($MTCO_2e$)	Cost per Ton of GHG Reduced ($/ton of CO2e)
Use agricultural best practices	**208,331**	**328,070**	**-$22**
Increase and provide training for no-till farming practices	208,331	328,070	-$22

[14] This includes some emission reductions from energy consumption due to changes in fuel consumption by agricultural equipment.

Use Agricultural Best Practices

Agricultural best practices will allow farmers to maintain or increase productivity sustainably into the future while also accounting for expected climate changes.

Leadership Actions

Policies, plans, and government activities can encourage the adoption of best practices. State and local leaders can:

- **Increase adoption rate of and provide training for no-till farming practices**, especially those that sequester carbon in soils and plants. To take this action, the Pennsylvania Department of Agriculture should build upon existing programs, such as the Workforce Development initiative which has the intent of promoting and expanding the state's agriculture education opportunities, as well as career and technical education programs. In establishing education materials and trainings for no-till farming, the Department of Agriculture could partner with the Penn State Extension to utilize the training resources that have already been developed and are in use, or other resources such as those found at the United States Department of Agriculture. For example, a four-part video series which highlights knowledge and experience from farmers in Pennsylvania already using no-till practices is already available online: https://extension.psu.edu/no-till-farmer-to-farmer-introduction-to-the-series. These programs and materials should focus on sharing best practices between farmers and on educating farmers on the benefits (economic and environmental) of no-till farming practices.

The above action in **bold** is reflected in the quantified key metrics below. Other actions leaders can take include:

- Expand integrated farm management and conservation planning, including:
    - Energy conservation and renewable energy generation such as digesters for methane capture and recovery, energy efficiency, and the production and use of renewable energy (e.g., biofuels, solar, wind).
    - Best practices to manage flooding, including agriculture that is compatible with periodic flooding, establishment or restoration of riparian buffers, wetland easements for marginal and flood-prone agricultural lands, switchgrass planting programs for soil and bank stabilization, and research on the benefits of periodic fallowing for active floodplain acres.
    - Best practices related to runoff and nutrient management such as runoff reduction strategies; pesticide, herbicide, fertilizer, and nitrogen reduction programs; and efforts to ensure that manure is land-applied only at agronomic rates.
    - Advanced irrigation systems such as GIS, GPS, and satellite crop and soil moisture sensing systems.
    - Plant drought-tolerant hybrid species in upland areas to reduce need for irrigation.

- Expand regional planning initiatives, especially in agricultural areas, focusing on agricultural security zones and local food security.
- Revise/update existing conservation and agricultural measures to see how they could further support resilience to climate change and modify where necessary.
- Provide financial incentives and support for agricultural best practices, such as:
    - Sales or property tax exemptions, rebates, and reduced agricultural insurance rates.
    - Agricultural insurance requirements to factor climate risk reduction benefits of management best practices in rates.
    - Economic and cooperative structures that transfer risk away from the bank and farmer, such as Community Supported Agriculture (CSA).
    - Pricing systems that reward conservation (e.g., seasonal pricing).

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

Encouraging and adopting agricultural best practices can offset some of the negative impacts of increased temperatures, pests and diseases, and changing precipitation patterns. Agricultural best practices can result in:

- Increased or maintained agricultural productivity, allowing farmers to take advantage of opportunities presented by climate change.
- Improved sustainability of agricultural practices to cope with changing climatic conditions.
- Reduced erosion and improved soil quality across the state.
- Improved water quality which will be negatively impacted by changing precipitation patterns and increased runoff, thereby protecting the health of Pennsylvania's citizens.
- Conserved water resources, which are expected to be increasingly strained.

Environmental Benefits & Costs

Several of the aforementioned climate resilience benefits are also environmental benefits, including reduced erosion, improved soil quality, improved water quality, and water resource conservation. Agriculture can be a carbon sink, and proper management reduces the GHG emissions as well (Agriculture and Agri-Food Canada 2000). Good soil management reduces erosion and soil degradation, which can be damaging for the agricultural sector and for waterways impacted by sedimentation (McRae, Smith, and Gregorich 2000). Reducing runoff also lowers the amount of nitrate runoff from agricultural land, which contributes to water pollution and eutrophication. Also, water conservation in irrigation will help preserve groundwater and surface water resources.

Economic Benefits & Costs

Agricultural best practices can promote economic stability for farmers by increasing or maintaining agricultural productivity. This adds to the GSP and creates or maintains local jobs. Additionally, as shown below, fuel costs are reduced, offering savings for farmers.

Key Metrics

Net Present Value: $162 Million[a]

Cost-per-ton of GHG Reduced: - $22/$MTCO_2e$[b]

	2025	2050		2025	2050
	BBtu Fossil Fuel Consumption Reduced[c]				
	294	462			
	$MTCO_2e$ GHG Emissions Reduced			***MT Air Pollutants Emissions Reduced[d]***	
	208,331	328,070	NO_x	-18	27
			SO_2	-0.2	-0.3
	Capital Expenditures ($ Million)			***Maintenance & Repair Savings ($ Million)***	
	$14	$22		$12	$19
	Number of Jobs Supported			***Impact on GSP ($ Million)***	
	470	-495		$0.00	-$12
	Energy Expenditure Savings ($Million)[e]			***Change in Disposable Personal Income Per Household ($/Household)***	
	$6	$12		$0.24	-$5

[a] *Net Present Value for this strategy includes capital expenditures, energy savings, lost revenues, and maintenance and repair costs.*

[b] *Negative cost-per-ton indicates cost savings.*

[c] *This strategy affects natural gas, distillate fuel oil, liquefied petroleum gas (LPG), kerosene, and motor gasoline consumption. Note that there is a small amount of biodiesel blended into the distillate fuel oil that was not estimated in this strategy.*

[d] *Emission factors for Hg emissions from LPG and kerosene consumption were not readily available. Negative reductions indicate increases compared to BAU.*

[e] *Energy Expenditure Savings in this strategy represent energy bill savings on natural gas, distillate fuel oil, LPG, kerosene, and motor gasoline.*

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU. Negative cost-per-ton represents net cost savings.

Key Analysis Assumptions:

- *Quantified metrics reflect the policies, programs, and action in* **bold** *above.*
- *No-till total acres planted in Pennsylvania will increase by approximately 2 percent annually based on the U.S. Department of Agriculture (USDA) Pennsylvania Tillage Survey statistics for 2013 and 2014 (USDA 2014).*
- *Planted acres of crops stay consistent over time through 2050 and conventional tillage acres will transition to reduced tillage acres, and reduced tillage acres will transition to no-tillage acres.*

- *Emission reductions and yield changes by crop/tillage practice are estimated using Northeast data from USDA's report Greenhouse Gas Mitigation Options and Costs for Agricultural Land and Animal Production within the United States (USDA 2013).*
- *Fuel savings are in line with USDA regional estimates of fuel consumption ($/acre) for various tillage practices to the projected estimates of conventional, reduced, and no-till acres in Pennsylvania*

Other Key Performance Indicators

Example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Yield
- Land use intensity
- Share of agricultural land enrolled in agricultural preserve programs
- Food production per unit of GHG emissions
- Share of farm area with agricultural GHG emissions management practices
- Share of arable land under soil conservation practices/conservation agriculture

What You Can Do to Increase Use of Agricultural Best Practices

- ► Support sustainable farming in personal purchasing decisions (e.g., subscribe to a CSA).
- ► Reduce personal food waste through improved storage methods and planning.
- ► Participate in community composting programs.

What Businesses Can Do to Use Agricultural Best Practices

Pennsylvania **farmers** can support this strategy by taking the following actions:

- ► Protect crops from heat and drought, including:
  - Diversify cropping systems including planting drought-tolerant varieties to reduce water consumption and defend against drought.
  - Adjust the selection of planting dates (e.g., earlier planting and harvesting dates to avoid arid late-summer conditions).
  - Integrate agro-forestry practices into cropping systems.
- ► Sustainably manage soil and protect water resources, including:
  - Use soil conservation techniques and conservation tillage methods (e.g., no-till, mulching, strip till) to increase water infiltration and soil organic matter.
  - Protect environmentally sensitive agricultural land through enrollment in the Conservation Reserve Program or other, similar programs.
  - Use intensive/rotational grazing as opposed to cropping and feeding animals indoors.
  - Use cover crops and water-holding crops to enhance soil water retention, reduce erosion, and improve water quality.
  - Improve water use efficiency in agricultural buildings and processing facilities.
  - Deploy a nutrient management plan and manage manure responsibly
  - Use carefully prescribed pesticide and nutrient application practices, such as no winter nutrient application and application at agronomic rates.
- ► Employ organic farming techniques and increase chemical-free forms of pest control.

Provide Resources and Technical Assistance to Farmers to Adapt

Many farmers lack access to climate data or do not know how to change their practices to reduce risk from climate change. Providing technical assistance and other support can help farmers make better decisions about sustainable farm management and how to protect their crops.

Leadership Actions

Actions under this strategy fall into two main categories: (1) improve monitoring and data dissemination, and (2) fill research needs and disseminate results.

Having access to accurate and timely weather and climate information allows farmers to make better decisions about their crops and planting cycles. Actions to improve monitoring and data dissemination in the near-term include:

- Establish a network of agro-meteorological stations statewide to collect climate observations, including estimates of evapotranspiration, to support research and development of agricultural practices.
- Expand the collection and dissemination of local weather information for irrigation planning.
- Improve the accuracy of existing real-time weather warning and forecasting systems for drought and extreme events.
- Develop and disseminate seasonal climate forecasts.
- In addition, several of the long-term impacts of climate change in Pennsylvania are not well understood. State leadership can take action to fill those research gaps and disseminate the results to the agricultural community, including the following actions:
- Conduct or sponsor research to understand topics such as climate change effects on weeds, insects, and diseases; best practices for agricultural emergency response plans; conservation best practices; and methods for maintaining the genetic diversity of crops.
- Facilitate information sharing networks for farmers and the agricultural research community to share experiences and best practices.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

Providing technical assistance will provide farmers with the resources they need to make informed decisions about how to manage changing climatic conditions. This has the benefits of:

- Reduced crop and animal product losses due to heat stress or changing precipitation, thereby preventing economic losses.
- Maintained and improved soil health that will help maintain crop yields over time.
- Reduced damages and costs from pests and diseases.

Environmental Benefits & Costs

As described under the previous strategy, actions to mimic natural pest management systems and sustainable farming practices can improve soil and water quality, and preserve ecosystem health. If used responsibly, integrated pest management will have insignificant environmental impacts. However, if chemicals are not handled or dispersed properly, they could negatively affect wildlife, including bees (CDC 2017b).

Economic Benefits & Costs

All of the aforementioned climate resilience benefits can result in preserved economic activity from the agricultural sector. In addition, technical assistance and the resulting resilience benefits can result in economic benefits for individual farmers and the 280,500 people directly employed in agriculture within the state (PA Department of Agriculture 2018).

Key Performance Indicators

Example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Number of farmers involved in technical assistance networks
- Number of persons assisted/trained through outreach programs
- Investment in research and development
- Number of crop insurance claims/year
- Yield of key crops and animal products

What You Can Do to Support Resources and Technical Assistance to Farmers to Adapt

Pennsylvania citizens can support this strategy by buying local farm products to support local farmers, and encouraging businesses (e.g., restaurants and grocers) to do the same.

What Businesses Can Do to Use and Support Resources and Technical Assistance to Farmers to Adapt

Pennsylvania **farmers** can support this strategy by taking the following actions:

- ► Work with state and local leadership to communicate observed climate impacts and needs for technical support.
- ► Participate in technical assistance programs.
- ► Make use of information and technical assistance resources provided by state agencies and other sources.
- ► Monitor trends in weather and productivity to inform future decision-making.
- ► Increase adoption of techniques that replicate natural systems' mechanisms for pest control and disease management.
- ► Consider diversifying or supplementing crops with solar panels to counterbalance climate-related crop risks.

In addition, **restaurants** and **grocers** can procure local produce to support local farmers.

Ecosystems and Forestry

Pennsylvania's ecosystems include forests, wetlands, and coastal ecosystems.

The dominant ecosystem in the Commonwealth of Pennsylvania is the forest. Pennsylvania has 17 million acres of forested land, covering 59 percent of its total land base and is the largest single cover type. Common trees present in Pennsylvania forests are oak, maple, and cherry. These trees provide economically important products for the state's economy such as lumber and maple syrup. Furthermore, forests support diverse plant and animal life and protect the state's watershed. The Plan also recognizes the importance of GHG sinks in climate change mitigation: while no quantitative goals have been set for sinks, afforestation, reforestation, sustainable agriculture, and other natural-system improvements can provide significant reductions in net emissions by removing GHGs from the atmosphere. Pennsylvania's forests serve as one of these important carbon sinks, and in 2018 state forests are projected to sequester 5.14 million tons of carbon, while storing 158 million tons above ground (PA DCNR 2015, DCNR, personal communication).

Conserving forest land, maintaining forest health, planting trees, and promoting a vibrant wood products industry are effective, low-cost contributions that mitigate the impacts of climate change while also offering many additional social and environmental benefits (PA DCNR 2015).

Wetlands are another important ecosystem in Pennsylvania. These are areas which are saturated with water and can occur in floodplains along rivers and streams, in swamps or marshes, and along the edges of lakes. Wetlands are vital breeding and spawning grounds for many animals such as fish and amphibians. In fact, these ecosystems are home to some of Pennsylvania's threatened and endangered species, like the American bittern (Sothern 2017).

A coastal ecosystem is found where the lands meets the sea. In Pennsylvania there are two coastal areas: 77 miles of coastline along Lake Erie and 112 miles of coastline along the Delaware Estuary (PA DEP). These zones encompass a diverse set of habitat types that include both terrestrial and marine areas. The uniqueness of coastal ecosystems gives them large social, economic, and biological value. Many people in Pennsylvania rely on the provisioning services of coastal zones for their food supply and livelihoods and this ecosystem contributes to several economic sectors such as fisheries and tourism.

Climate Change Impacts

The expected impacts of climate change on ecosystems and forestry in Pennsylvania (Shortle et al. 2015) include:

- Shifts of suitable habitat to higher latitudes and elevations; species inhabiting decreasingly suitable habitat could become stressed due to warmer temperatures.
- Threats to ocean resources, particularly in the tidal freshwater portion of the Delaware estuary, due to decreases in dissolved oxygen concentrations.
- Damage to coastal wetlands due to sea level rise and salinity intrusion. Coastal wetlands provide many environmental benefits, including flood protection, erosion control, improved water quality, and fish and wildlife habitat.

- Reduced stream and wetland community health due to temperature increases and precipitation changes.
- Reduced suitable habitat for fish and wildlife.
- Shifts in forest tree species composition with impacts to many forest-dependent wildlife species, migrants, and to the $5.5 billion PA forest products industry.

Healthy ecosystems and forestry provide 90,000 forest jobs and $5.5 billion in forest products annually, a large number of timber and non-timber forest products, physical and mental health benefits, clean air, habitat for most wildlife and plant species in Pennsylvania, aquifer recharge, draws for in-state and out-of-state tourists, visitor dollars that support forest and park-adjacent communities, and many more benefits to Pennsylvanians.

Opportunities to Reduce Emissions and Adapt to Climate Change

In the Ecosystems & Forestry sector, DEP has identified two main strategies to reduce emission and adapt to climate impacts:

- **Protect ecosystem resilience, including forest systems where species will shift**
- **Monitor, identify, and address ecosystem vulnerabilities**

Each strategy description below includes leadership, citizen, and business actions that support the strategy; a summary of strategy benefits and costs; and key performance indicators.

The team did not quantitatively analyze actions within Ecosystems & Forestry strategies.

Protect Ecosystem Resilience, Including Forest Systems Where Species Will Shift

Ecosystems within Pennsylvania provide significant value through ecosystem services, natural resources, and recreational opportunities. Maintaining healthy ecosystems capable of supporting fish and wildlife populations, as well as preserving ecosystem function and recreational use, is critically important, especially as the ecosystems are under increasing stress due to climate change.

Leadership Actions

Pennsylvania can protect green spaces and ecosystems upon which wildlife, fish, and recreation depend through actions such as the following:

- Conserve and enhance areas representing the full range of wildlife and fish habitats and promote connectivity (e.g., using land exchanges, conservation easements, leases; by removing barriers) to allow species to migrate to suitable habitat.
- Promote forest conservation, reforestation and urban tree canopy expansion on private and public lands through various means, including funding a statewide forest conservation easement program.
- Restore wetlands and riparian areas, expand or revise current minimum riparian buffer zones, and implement living shoreline programs to provide natural flood abatement, breeding habitat, and improved stream conditions (including improved thermal conditions).

- Preserve and create open spaces, parks, and trails that allow people to continue to engage in outdoor activities and maintain connectivity to natural resources. Protect wildlife and fish habitat and species that support recreational opportunities like hunting, fishing, and wildlife viewing.
- Educate recreational land users about the importance of climate change impacts on ecosystems and the dangers of illegal hunting and fishing, pollution, and development.
- Retrofit existing parks and trails and create new parks and trails to strengthen the community, improve habitat connectivity, provide more water sources for human users recreating in higher temperatures, enhance natural stormwater and flood management, and connect paths to schools, workplaces, and retail centers to promote pedestrian use.
- Promote alternatives to mowing, including meadows, native plants, and trees.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

The climate resilience benefits of protecting ecosystems and promoting optimal use include:

- Protected resources and ecosystem services for recreation, hunting, fishing, and drinking water.
- Restored and protected habitat for wildlife, including allowing populations to shift to adapt to increased temperatures.
- Maintenance of key migration routes for vulnerable species.
- Improved water quality.
- Reduced temperatures in stream and wetland ecosystems, which protects fish populations from heat stress and productivity loss.
- Reduced damage to aquaculture, fisheries, and recreation by protecting fish populations from habitat destruction and cutting off migration.
- Reduced heat island effects caused by rising temperatures, which will reduce heat stress and health impacts due to climate change.
- Reduced impacts from flooding in urban areas caused by more intense precipitation by providing stormwater management.
- Continued outdoor recreation opportunities despite rising temperatures, providing benefits for health and the tourism industry.

Environmental Benefits & Costs

Environmental benefits of effective ecosystem management include improved water quality, reduction of runoff, healthier habitats, and healthier wildlife and fish populations.

The GHG emission reduction benefits of ecosystem protection include:

- Reduced atmospheric carbon dioxide through protected and restored carbon stocks.
- Reduced carbon and other air emissions when people hike or bike on trails instead of driving their vehicles.
- Reduced atmospheric greenhouse gas and pollution impacts due to carbon sinks.

Urban and suburban areas receive multiple benefits from increased forest cover, some of which include improved air quality, greater natural beauty (and property values), and added value to the ecosystem. In addition to removing carbon and other greenhouse gases from the atmosphere, well-placed trees offer benefits, such as energy savings for property and vehicle owners, groundwater filtration, and reduced runoff and flooding, just to name a few (PA DEP 2015).

Economic Benefits & Costs

Trees that are placed in close proximity to a home can also help to reduce the owner's energy costs by as much as 30 percent. During the summer, the shade that trees provide is a natural way to keep energy bills low, as it prevents the sun from heating the home and lessens the energy required to maintain a cool temperature. Properly placed trees also serve as windbreaks during the winter and shield homes from icy winds that would otherwise result in increased heating costs (PA DEP 2015).

Efforts to plant more trees in Pennsylvania are well underway, in large part because of TreeVitalize, a public-private partnership established by DCNR. The program aims to restore tree cover in Pennsylvania communities by providing technical and financial assistance on tree planting, tree improvements, and urban tree canopy assessments; training citizens on how to select, plant, and maintain trees in their local areas; and publicizing the numerous benefits of tree planting through partnerships with local sports teams and public radio stations.

Since its inception in 2004, more than 461,627 TreeVitalize trees have been planted in urban and suburban areas throughout the commonwealth. As of 2018 this provided a reduction in 1.6 billion gallons of stormwater and a savings of $12.8 million; a reduction of 41,611 pounds of nitrogen; sequestration of 235 million pounds of carbon; and a 41 million kWh decrease in electricity consumption and $5.7 million in savings, among other things (PA DCNR, 2018, personal comm.).

Possible actions within this strategy range from low to high cost. For example, a low-cost action is choosing native plants for gardens or landscaping. A higher cost action is installing fish ladders at hydroelectric dams. The cost of a fish ladder is proportional to the height of the dam and may cost $10,000-30,000 per foot (Connecticut River Watershed Council 2000).

The economic benefits of these actions include improved ecosystem services that provide recreation, flood protection, drinking water, and food sources. Outdoor recreation is enjoyed by 56% of residents each year and brings in $29.1 billion in customer spending and directly employs 251,000 people (PA DCNR 2017). Additionally, studies show urban tree planting can greatly reduce medical costs and prescription needs. One such study found annual nationwide reduced medical costs of $6.8 billion from adding more greenery to cities (USDA 2018).

Key Performance Indicators

Example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Trees planted in urban or community areas
- Number of endangered or threatened species
- Percentage of stocks overfished/degree of overfishing
- Amount of buffer zone protected

- Area and percent of forest land managed primarily for protective functions, e.g. watersheds, flood protection, riparian zones, and using management protocols certified sustainable by The Sustainable Forest Initiative, Forest Stewardship Council, TreeFarm USA, or other third-party organizations.
- Total forest ecosystem biomass and carbon pool, and if appropriate, by forest type, age class, and successional stages

What You Can Do to Protect Ecosystem Resilience

Pennsylvania citizens can support this strategy by taking the following actions:

- ► Choose native plants for your garden to conserve water and protect habitat.
- ► Use alternatives to lead bullets while hunting to protect vulnerable species.
- ► Participate in local conservation activities. For example, join a local land trust.
- ► Support parks and trails in your area by using recreation areas.
- ► Protect open spaces, parks, and trails by joining a state park or forest Friends group or local chapter of a conservation nonprofit.

What Businesses Can Do to Protect Ecosystem Resilience

Pennsylvania businesses can support this strategy by taking the following actions:

- ► Support local conservation organizations and activities.
- ► Choose native plants for landscaping to conserve water and protect habitat.
- ► Allow fish to safely pass around hydroelectric dams using effective techniques and technologies.
- ► Use green infrastructure and water management features that promote infiltration and reduce runoff.
- ► Minimize construction in key habitat areas.
- ► Increase and maintain access points (e.g., walking trails) in and around lake and river recreation areas rather than impervious infrastructure.
- ► Maintain dirt biking trails and educate riders to minimize the environmental impacts of additional trail usage.

In addition, **farmers** can also play a role by taking the following actions:

- ► Use best management practices (BMPs) on agricultural lands and barnyards to limit polluted runoff that might damage ecosystems.

Monitor, Identify, and Address Ecosystem Vulnerabilities

Developing better research on how climate change may affect Pennsylvania's ecosystems and green spaces is necessary to manage them more sustainably. It is also important to continue to monitor environmental impacts to these areas to establish adaptive thresholds.

Leadership Actions

State and local leaders can take action to identify and study key ecosystems to better understand the vulnerabilities they could face. Actions include:

- Develop a central database to store relevant ecosystem data.
- Establish a statewide monitoring and research network of academics, civil society, and citizen scientists to establish baseline conditions and monitor ecosystem factors, such as physical changes, species distribution (including invasive species), weather conditions, disease outbreaks, and general ecological conditions, and adequately fund and staff the existing PA Invasive Species Council.
- Identify and prioritize species, habitat, and ecosystems most vulnerable to climate change and other stressors to better target protection and management actions.
- Review existing legal, regulatory and policy frameworks that govern protection and restoration of wildlife and fisheries habitats, and identify opportunities to improve their ability to address climate change impacts.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

The climate resilience benefits of monitoring and research on ecosystem vulnerabilities to climate change, and removing those vulnerabilities include:

- Better informed management to reduce threats to habitat.
- Improved ecosystem protection to provide key ecosystem services.

Environmental Benefits & Costs

This strategy promotes long-term environmental health and ecosystem services. Monitoring and identifying vulnerabilities enables the state or individuals to respond when a problem is detected and protect natural resources through adaptive management approaches.

Economic Benefits & Costs

This strategy is a low-cost way to prepare today so that Pennsylvania is able to respond appropriately over time to protect key ecosystems and economies. For example, healthy hardwood forests account for about 58% of the state's land cover and contribute to a strong forest products industry, which employs more than 86,000 people (Pennsylvania Forest Products Association 2003). Having the right information to appropriately manage forests under changing climatic conditions can help protect jobs and industry. In addition, better information can help to manage species migration that could negatively affect hunting, fishing, and wildlife watching activities, which are a small, but important part of the state's economy. In 2011, in-state hunting and fishing expenditures totaled around $1.5 billion and wildlife

watching activities totaled around $1.3 billion (U.S. Department of the Interior and U.S. Department of Commerce 2013).

Key Performance Indicators

Example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Number of species included in monitoring activities
- Habitat extension, size, and representativeness
- Spatial connectivity
- Population density of target species
- The status (threatened, rare, vulnerable, endangered, or extinct) of forest dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment

What You Can Do to Monitor, Identify, and Address Ecosystem Vulnerabilities

Pennsylvania citizens can support this strategy by taking the following actions:

- ► Participating in "citizen science" programs, such as iNaturalist (https://www.inaturalist.org/) or the Great Backyard Bird Count (http://www.nepaaudubon.org/birding/bird-counts/) to monitor changing ecological conditions over time.
- ► Volunteer with local tree-planting and wildlife habitat creation efforts.

What Businesses Can Do to Monitor, Identify, and Address Ecosystem Vulnerabilities

Pennsylvania businesses can support this strategy by taking the following actions:

- ► Sponsor and participate in "citizen science" programs to monitor changing ecological conditions over time.
- ► Partner with research institutions as appropriate to support monitoring and research efforts.
- ► Sponsor and participate in tree-planting and wildlife habitat creation.

Outdoor Recreation and Tourism

Pennsylvania's 120 state parks, over 5,000 miles of rivers and streams, and 2.2 million acres of state forests attract visitors from all over the globe and foster outdoor activities such as hiking, skiing, biking, bird watching, and kayaking (Wilgus 2014).

Outdoor recreation brings visitors to an area and the communities reap the economic benefits when visitors buy food, stay overnight in hotels, buy or rent equipment, and pay for travel costs. For this reason, Pennsylvania's abundant tourism opportunities at treasured destinations have caused the travel and tourism sectors to be critically important for the residents as well as the economy of the state. Outdoor recreation is among the nation's largest economic sectors. In Pennsylvania, outdoor recreation generates $29.1 billion in consumer spending annually as well as provides 251,000 direct jobs (Outdoor Industry Association 2017). Overall, tourism supports 6.5% of jobs in the state, which includes almost 319,700 direct jobs, and nearly $4.1 billion of state and local taxes (Tourism Economics 2015). Tourism has also been growing more quickly than the state's broader economy.

Climate Change Impacts

The expected impacts of climate change on outdoor recreation and tourism in Pennsylvania (Shortle et al. 2015, DCNR 2018) include:

- Longer outdoor recreation seasons and an overall increase in outdoor recreation participation.
- Potentially increased demand for water-based recreation due to higher summer temperatures.
- Potentially increased participation in recreational fishing due to a longer season, offset by potential declines in fish populations due to reduced summer streamflow, reduced water quality, and increased potential for eutrophication.
- Increased costs and decreased profits for winter recreation. For example, ski resorts will experience shorter seasons, higher snowmaking costs, and lower profits.
- Increased adverse health effects associated with outdoor recreation such as from heat or ticks.

These changes could alter the nature of a major economic sector in Pennsylvania.

Opportunities to Reduce Emissions and Adapt to Climate Change

In the Outdoor Recreation and Tourism sector, the analysis team has identified one main strategy to reduce emission and adapt to climate impacts:

- Help the outdoor tourism industry manage shifting climate patterns.

The strategy description below includes leadership, citizen, and business actions that support the strategy; a summary of strategy benefits and costs; and key performance indicators.

This strategy does not include actions that the team quantitatively analyzed.

Help the Outdoor Tourism Industry Manage Shifting Climate Patterns

The outdoor tourism industry is an important pillar of the Pennsylvania economy that is expected to experience changes—both positive and negative—as a result of climate change. Providing assistance and support to the industry to understand and manage anticipated impacts will help the industry maximize the benefits and minimize the negative impacts of climate change.

Leadership Actions

State and local leaders can build strategic collaborative partnerships to engage citizens and communities in adapting and conserving special places within Pennsylvania in the face of climate change. For example, leaders can:

- Establish a formal climate change working group building on existing partnerships, comprised of commonwealth agencies, federal agencies, academic institutions, the business community, and environmental NGOs.
- Help public parks adapt to climate change by designing park infrastructure to be adaptable to changes in use, allocating funds to match recreation demand, and expanding operations at ski resorts to allow for warm-weather recreation.
- Explore developing new collaboratives with surrounding states.
- In addition, state and local leaders can provide technical assistance, education, and other resources to help the private sector respond to climate changes. For example, leaders can:
    - Create a business ombudsman or technical assistance center for affected recreational industries and establish a source of grant funding or tax incentives to help industry and municipalities transition from winter to summer activities.
    - Educate facilities about diversification opportunities for more warm-weather or cold-weather activities (e.g., ski slopes can maintain mountain bike trails for warm weather) with consideration of environmental impacts.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

The climate resilience benefits of building networks and helping the outdoor tourism industry adapt include:

- Reduced economic impacts to snow-based winter tourism due to increased temperatures.
- Reduced public health impacts due to changing climatic conditions.
- Higher economic activity in locations that can capitalize on more favorable conditions for outdoor recreation or a longer outdoor recreation season.

Environmental Benefits & Costs

Helping outdoor tourism providers plan for shifting climate patterns and manage changes will reduce the burden placed on natural resources environmental services. Working with industry can provide additional opportunities for conservation. For example, a ski resort adapting to shifting patterns can

reduce water consumption for manufactured snow and take advantage of off-season revenue opportunities. Additionally, using native plants in landscaping or golf courses will reduce the need for watering, thereby conserving water resources and protecting ecosystem health. Some of these solutions may also improve habitat quality.

Economic Benefits & Costs

This strategy is intended to support the outdoor recreation industry, which contributes $29.1 billion to the state economy annually (Outdoor Industry Association 2017). Actions can help the industry maximize the benefits and minimize the negative impacts of climate change. For example, seasonal tourist destinations could increase their revenue by attracting year-round or multi-seasonal tourists.

Key Performance Indicators

Example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Revenue from outdoor recreation, winter and summer
- Participation rates in outdoor recreation, by season
- Parks and recreation facilities with water conservation mechanisms
- Snow produced for recreation
- Number of facilities reached through education programs

What You Can Do to Help the Outdoor Tourism Industry Manage Shifting Climate Patterns

Pennsylvania citizens can support this strategy by taking the following actions:

- ► Participate in public participation processes related to helping the outdoor recreation industry adapt to climate change, such as supporting permit applications for summer use of ski areas.
- ► Use native plants and landscaping techniques to decrease water consumption, lessen impacts on groundwater and nearby streams, and decrease fertilizer use and carbon emissions from lawn maintenance.

What Businesses Can Do to What You Can Do to Help the Outdoor Tourism Industry Manage Shifting Climate Patterns

Outdoor activity providers can support this strategy by taking the following actions:

- ► Use native plants and landscaping techniques to decrease water consumption, lessen impacts on groundwater and nearby streams, and decrease fertilizer use and carbon emissions from lawn maintenance.
- ► Adapt golf course management towards increased water conservation and use of more native plants to decrease water consumption and lessen impacts on groundwater and nearby streams.
- ► Augment fishing and boating access, adapt for longer seasons, and provide more dock slip space.
- ► Manage water on-site at all parks and recreational centers using green infrastructure and conservation mechanisms.

Pennsylvania **ski resorts** can play a role by taking the following actions:

- ► Promote and market summer activities at ski resorts.
- ► Raise awareness for how citizens and visitors can exploit larger, infrequent snowfalls, such as through snow tubing, cross-country skiing, snowshoeing, and snowmobiling.

- Strategically plant and retain trees to capture moving snow and to shade ski slopes to reduce snowmelt, thereby reducing snowmaking needs.
- Retain snow by using snow breaks and fences, as well as improve snowmaking capabilities.
- Use more efficient equipment to reduce revenue losses and strain on energy and water resources.

Waste Management

Waste consists of any unwanted or unusable material that is discarded. It can be divided into several main categories such as municipal, residual, and hazardous waste. Waste management collectively refers to the collection, transportation, processing or treatment, and disposal of waste.

GHG emissions in the waste management sector come from landfills (primarily in the form of landfill gas), waste-to-energy facilities (primarily from the combustion of solid waste), and wastewater treatment plants (from the digestion of biosolids). Second tier emissions occur from waste transportation and related activities.

Currently in Pennsylvania there are 43 municipal waste landfills, 3 construction and demolition waste landfills, 6 waste-to-energy facilities, 95 material recovery facilities, approximately 260 composting facilities, and 14 permitted digesters for manure and food waste (PA DEP 2015). The municipal waste industry in Pennsylvania collects, hauls, and disposes of 8.6 million tons of municipal solid waste annually (Econsult Solutions 2013).

Pennsylvania has been a national leader in recycling rates, and recently the statewide recycling rate was as high as 35%. The amount of materials recycled grew from 4.8 million tons in 2006 to 5.85 million tons in 2011, a 20% increase. Of this, 30% is exported as recycled commodities (Econsult Solutions 2013). Unfortunately, recycling rates are falling across the commonwealth and country due to the elimination of a significant portion of worldwide recycling processing capacity. Many local governments in Pennsylvania are scaling back or eliminating their recycling programs due to the increased cost and lack of market for the recyclable materials.

In addition to the potential of income from recycling when the markets recover, the waste sector provides positive economic impacts, such as landfills generating about $250 million in taxes and fees to state and local governments in addition to direct annual operating expenditures (Econsult Solutions 2013). Overall, the municipal waste industry in Pennsylvania has a total economic impact of more than $4.2 billion a year and provides an array of job opportunities supporting more than 26,000 jobs (Econsult Solutions 2013).

Climate Change Impacts

The expected impacts of climate change on landfills nationally (EPA 2017f) and WTE facilities include:

- Larger quantities of waste resulting from natural disasters.
- Difficulties in segregating disaster-related wastes for proper disposal.
- Increased need for transportation of disaster-related wastes.
- Strains on waste management capacity to handle surges in these types of wastes.
- Direct impacts to waste management facilities.

The expected impacts of climate change on WWTP include:

- Higher inflows both average and peak
- Power outages due to storm impacts

Fortunately, Pennsylvania's state government has been at the forefront of developing and implementing plans to address the possible impacts of climate change on waste disposal facilities, particularly as it relates to disaster response.

Opportunities to Reduce Emissions and Adapt to Climate Change

In the Waste sector, DEP has identified one main strategy to reduce emissions and adapt to climate impacts:

- **Reduce waste generation by citizens and business, thereby reducing waste sent to landfills and WTE facilities and expand the beneficial use of waste.**

The strategy description below includes leadership, citizen, and business actions that support the strategy; a summary of strategy benefits and costs; and key performance indicators.

The team did not qualitatively analyze actions included in this strategy.

Actions related to this sector that will reduce GHG emissions by the beneficial use of LFG are also found under the "Increase Production and Use of Alternative Fuels" strategy within the "Energy Production" sector.

Reduce Waste Generation by Citizens and Business, Thereby Reducing Waste Sent to Landfills and WTE Facilities, and Expand the Beneficial Use of Waste

As noted above, reducing the amount of waste generated, and increasing the amount that is recycled or beneficially used can reduce GHG emissions and provide economic benefits for the commonwealth. An example is diverting biodegradable waste from disposal to beneficial uses, such as substituting for an existing product. Continuing to build on the efforts already in place to reduce waste generation and reuse or recycle that waste which is generated is a necessary part of Pennsylvania's sustainable economy.

Leadership Actions

The Commonwealth of Pennsylvania plans to advance this strategy by pursuing a selection of the following policies, programs, and actions.

- Implement programs to encourage citizens and business to reduce waste generation (including food waste) and use recycling and composting programs through reduce, reuse, and recycle actions.
- Encourage the use of digesters for methane capture and recovery.
- Support solar projects on landfill land.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

Reducing waste sent to for disposal and increasing the amounts of waste recycled or beneficially used can:

- Preserve resources and energy from the production of unused/unnecessary products and food.
- Increase the amount of alternative energy produced.
- Avoid the combustion of fossil fuels for the production of heat by replacing it with waste heat from WTE facilities.
- Capture methane to use as an alternative energy source, which reduces stress and can increase reliability of the energy grid.

Environmental Benefits & Costs

Reducing waste has several environmental benefits, including:

- Reduced GHG emissions, from waste disposal and overall lifecycle GHG emissions (e.g., for transporting waste to landfill sites).
- Reduced pollution through reuse/recycle.
- Reduced environmental degradation caused by landfills.
- Using recycled products requires less energy use than manufacturing using raw materials, resulting in less GHG emissions and air pollutants.
- Recycling paper products results in the need for fewer trees to be cut down, offering more carbon sequestration potential.

Additionally, landfill gas offers an additional alternative energy resource, which offers environmental benefits as described in the Increase Production and Use of Alternative Fuels Section of this Plan.

Economic Benefits & Costs

As indicated in the beginning of this Sector discussion, reducing the generation of waste and recycling or beneficially using it offers economic benefits and costs for Pennsylvania, such as:

- Revenue streams and taxable activity from use of recycled materials or gas for energy.
- Personal income savings from only buying what you need and repairing as opposed to buying new (which is often cheaper).
- Job creation to handle and use recycled materials.

A recent EPA study, the *Recycling Economic Information (REI) Report*, indicates that in 2007, the United States recycling industry resulted in 757,000 jobs (1.57 jobs for every 1,000 tons of materials recycled), $36.6 billion in wages; and $6.7 billion in tax revenues (EPA 2016d).

Key Performance Indicators

Example indicators that Pennsylvania could use to measure progress toward this strategy include:

- The total amount of landfill gas that is collected versus how much of it is beneficially used.
- The recycling rate in Pennsylvania
- Number of illegal dump sites
- Number of companies/jobs in the recycling/waste minimization sector

What You Can Do to Reduce Waste Sent to Landfills and WTE Facilities, and Expand Beneficial Use of Waste

Pennsylvania citizens can support this strategy by taking the following actions:

- Reduce personal production of waste through informed personal consumption decisions.
- Reuse or repair products to minimize waste; avoid purchasing single-use products.
- Recycle all recyclable waste via curbside pick-up or community recycling centers.
- Resell or donate items that are still in good condition but are no longer needed.
- Buy used items, goods made from recycled materials, and durable goods.
- Participate in community composting programs.
- Support solar energy and methane gas-to-energy projects at landfills.
- Do not dump illegally or burn waste.

What Businesses Can Do to Reduce Waste Sent to Landfills and WTE Facilities, and Expand Beneficial Use of Waste

Pennsylvania businesses can support this strategy by taking the following actions:

- Reduce waste used in business operations, such as reducing packing materials or transitioning from single-use materials to reusable materials.
- Recycle all recyclable waste materials.
- Introduce an office recycling program.
- Offer repair services of consumer products.
- Implement Environmental Management System that includes a waste reduction component, such as ISO14000
- Offer refurbished goods to customers at discounted prices.
- Analyze collection routes to reduce miles traveled and switch to alternative-fueled collection vehicles
- Use LFG for transportation and electricity generation or straight-piping to nearby industries.
- Increase the utilization of waste to heat at WTE facilities.

Water Resources

Pennsylvania's surface water resources comprise nearly 2.5 trillion gallons of water with around 86,000 miles of rivers and streams that flow through the state, more than 4,000 lakes, reservoirs and ponds, and 120 miles of coastal waters (Penn State Agriculture and Environment Center 2017). Thirty times more water lies below the surface in groundwater aquifers that rely on 40-plus inches of precipitation a year to be replenished (Abdalla and Blunk 2007). The commonwealth depends on these resources for drinking water, water for agriculture and industry, habitat for aquatic species, and recreational activities.

Pennsylvania's water resources are already subject to high demand from several user groups, such as thermoelectric power generators (70%), industrial and mining operations (13.6%), domestic and commercial customers (16%), and agricultural users (0.4%). The total withdrawal of surface and ground water in the state is around 10 billion gallons per day (Abdalla and Blunk 2007).

Many users in Pennsylvania, especially farmers and rural residents, depend on private wells for their water supply; for them, groundwater is the only option. More than one million private wells serve about 3.5 million people, about one quarter of the total population, and about 20,000 new wells are drilled each year in Pennsylvania (Swistock et al. 2009). Only Michigan has a larger population served by private wells. Studies have documented various water contaminants in private water systems, finding that 15-50 percent of private water systems fail at least one safe drinking water standard (Swistock et al. 2009). Contamination of groundwater wells can occur from failing septic systems, manure and fertilizer applications, oil and natural gas drilling, mining, or other land uses.

Climate Change Impacts

The expected impacts of climate change on water resources in Pennsylvania (Shortle et al. 2015) include:

- Increased saltwater intrusion due to rising sea levels, especially in the Delaware Estuary. This can alter habitats.
- Decreased water quality due to runoff from extreme precipitation events, urbanization, and increasing water temperature. This could result in higher water treatment costs.
- Reduced groundwater aquifer recharge, when precipitations occurs in more extreme events and a greater fraction runs off rather than infiltrating.
- Increased flood potential due to more extreme precipitation, and associated infrastructure impacts.
- Amplified risks to water resources associated with decreased snowpack, decreased water quality, urban flooding, and irrigation. This could result in higher water supply costs.

Opportunities to Reduce Emissions and Adapt to Climate Change

In the Water sector, DEP has identified two main strategies to reduce emissions and adapt to climate impacts:

- **Use stormwater best management practices**
- **Promote integrated water resources management and water conservation**

Each strategy description below includes leadership, citizen, and business actions that support the strategy; a summary of strategy benefits and costs; and key performance indicators.

These Water strategies do not include actions that the team quantitatively analyzed.

Use Stormwater Best Management Practices

With changing precipitation patterns, stormwater management is critical for reducing the likelihood and impact of floods.

Leadership Actions

State and local leadership can develop and enforce new policy requirements, revise existing policies, and provide incentives for improving stormwater management. These actions can include the following:

- Explore ways to incorporate PA DEP's *Stormwater Best Management Practices Manual* as standard operating procedure.
- Provide incentives for the installation and use of gray water and rainwater harvesting and consider existing international guidelines for increased reclaimed, recycled, and gray water use for non-potable applications (e.g., irrigation, toilet flushing).
- Revise stormwater regulations to accommodate increases in precipitation and run-off.
- Promote green infrastructure by instituting laws, regulations, and local ordinances requiring implementation of green infrastructure with new development or substantial redevelopment and revising the State Revolving Fund (SRF) state ranking criteria to require a thorough analysis and maximization of the use of green infrastructure, where appropriate. Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments. At the scale of a city or county, green infrastructure refers to the patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood or site, green infrastructure refers to stormwater management systems that mimic nature by soaking up and storing water. (EPA, 2014).
- Reduce impervious surfaces by requiring installation of permeable surfaces, buffers, and vegetated filters for all transportation-related projects; developing and enforcing a stormwater retention standard for new development and redevelopment; and/or implementing a fee for impervious surfaces.
- Promote, preserve, and manage natural features that treat, infiltrate, and hold runoff, such as riparian zones, estuaries, wetlands, floodplains, forests, and related landscapes.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

The climate resilience benefits of improved stormwater management include:

- Reduced flooding due to extreme precipitation events.
- Reduced heat island effect—which are exacerbated by higher temperatures—and associated health and air quality impacts.
- Protection of groundwater resources that are being depleted, particularly due to seasonal precipitation changes and reduced infiltration due to development.
- Reduced contamination of runoff, protecting the health of citizens and wildlife.

Environmental Benefits & Costs

In addition to the environmental benefits identified above, stormwater best management practices can capture carbon dioxide from the air and improve air quality through the use of green infrastructure. Green infrastructure solutions are low-impact, often no-regrets options that mimic natural systems. Primarily, green infrastructure can improve water quality, mitigate flooding, and build habitat.

Additionally, green infrastructure provides emission reduction benefits from reduced carbon dioxide emissions, carbon sequestration, reductions in water treatment and pumping energy requirements, and reductions in energy use due to cooling qualities of green roofs.

Economic Benefits & Costs

Additional modeling would be needed to quantify economic benefits, but improved stormwater management reduces the frequency and severity of urban flooding, which can result in significant economic benefits. Studies have shown that green infrastructure helps avoid capital costs for gray infrastructure, with a lower marginal cost (EPA 2014). Also, improved stormwater management will reduce the amount of runoff diverted to wastewater treatment plants, thereby reducing treatment costs.

Key Performance Indicators

Example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Investment in green infrastructure
- Area of impervious vs. permeable surface
- Total annual runoff
- Water quality (pH, phosphorous, nitrates, turbidity, conductivity, fecal coliform)
- Gallons of stormwater entering combined sewer systems
- Value of reduced flood damage

What You Can Do to Promote Stormwater Best Management Practices

Pennsylvania citizens can support this strategy by taking the following actions:

- Reduce impervious surfaces on your property.
- Install a rain barrel, rain garden, or other means to capture and use rainwater from roofs, driveways, and sidewalks.
- Plant vegetation on your property to slow and absorb runoff.

What Businesses Can Do to Promote Stormwater Best Management Practices

Pennsylvania businesses can support this strategy by taking the following actions:

- Maximize retention and ground infiltration of stormwater on-site at existing developed sites.
- Use bushes, mulch, rain gardens, permeable hardscape, or curb cuts in parking lot islands or in the areas between sidewalks and the roadway.
- Establish urban forests or plant street trees to reduce stormwater volume and pollutants.
- Develop erosion control and stormwater management plans for all construction sites.

Promote Integrated Water Resources Management and Water Conservation

Integrated water resources management involves coordinated development and management of water, land, and other resources to maximize economic and social well-being without compromising the environment. Pennsylvania can take a holistic approach to protecting water resources from the impacts of climate change, through planning and practices such as managing water quality, quantity, and use.

Leadership Actions

To implement informed water management policies and practices, leaders can:

- Support additional research on climate change impacts on water supply and basin hydrology, including with hydrologic models to project changes in surface runoff and groundwater.
- Assess the impact of climate change on critical water supply and wastewater infrastructure, and encourage the development of facility-specific adaptation plans.
- Include climate change projections and modeling results in water supply and water quality planning to enhance reliability, improve quality, and improve instream flows and fish passage.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

The climate resilience benefits of integrated water resource management include:

- Ensured long-term reliability of water supplies for drinking, agriculture, and other uses in the commonwealth.
- Improved water quality that could be degraded due to runoff from extreme precipitation events, resulting in reduced health risks of water-borne diseases and reduced environmental contamination.

Environmental Benefits & Costs

The climate resilience benefits associated with this strategy are also environmental benefits. Additionally, better water conservation practices often go hand-in-hand with energy conservation, sometimes leading to reduced environmental impacts from reduced energy usage.

Economic Benefits & Costs

Water conservation and efficiency is inexpensive compared to developing new water supplies, and treatment and distribution operations. For example, using a metering program allowed a utility in Gallitzin, Pennsylvania to identify leaks and initiate a leak repair program. Within four years of implementing the program, the city was saving $5,000 annually in chemical costs and $20,000 on power costs, which was significant for a system with approximately 1,000 connections (EPA 2002). Additionally, demand management can lower the operating and maintenance costs such as pumping and chemical costs for utilities (EPA 2016a).

This strategy will also reduce residential and commercial water bills. Just by fixing leaks, homeowners could save 10 percent of their water bill (EPA 2018b).

Key Performance Indicators

Example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Average/median gross water demand
- Water demand by sector
- Infrastructure Leakage Index rating
- Water savings from measure implementation
- Percentage per capita water demand reduction achieved

What You Can Do to Promote Integrated Water Resources Management and Water Conservation

Pennsylvania citizens can support this strategy by taking the following actions:

- Reduce household indoor water use by using water-efficient showerheads, faucets, and appliances (see EPA's WaterSense program for more information, available at https://www.epa.gov/watersense).
- Reduce outdoor water use, including by:
  - Plant native plants and drought-tolerant plants that don't require watering
  - Installing drip irrigation systems.
  - Setting sprinklers to keep the water on the landscape and off the pavement.
  - Managing sprinkler schedules to save water and money, updating schedules to align with the seasons.
  - Avoiding watering in the middle of the day when the sun will evaporate much of the water.
  - Contacting your local water utility to find out how much and when you should be watering outdoor plants.
- Set your pool water level several inches below the edge of the pool and plug the overflow line when the pool is in use or when adding water to avoid water loss from splashing.
- Use rain barrels or cisterns to harvest rainwater for irrigation and other outdoor water uses.

- Reuse household wastewater, called gray water, from bathroom sinks, showers, bathtubs, and clothes washers for landscape irrigation. Implement gray water reuse systems to divert water to a storage tank for outdoor watering use.
- Capture runoff on your property with rain gardens.

What Businesses Can Do to Promote Integrated Water Resources Management and Water Conservation

Pennsylvania businesses can support this strategy by taking the following actions:

- Install water-efficient technologies and better water-saving practices, such as toilets, faucets, laundry equipment, commercial ice machines, combination ovens, steam cookers, steam kettles, wok stoves, dipper wells, pre-rinse spray valves, food disposals, commercial dishwashers, and wash-down sprayers.
- Use non-potable water sources or reclaimed water for non-potable uses (e.g., industrial cooling, landscape irrigation) with adequate public health safeguards.
- Increase water recycling in industrial processes.
- Install smart water meters that allow different rates to be charged when overall system demand is higher.
- Monitor water use and educate facility staff, building occupants, employees, and visitors about water use and water management.
- Ensure that your facilities have leak detection and repairs performed regularly.
- Use soil moisture sensors that water plants based on their needs by measuring the amount of moisture in the soil and tailoring the irrigation schedule accordingly.
- Use rainfall shutoff devices and rain sensors to decrease water waste by turning off the sprinklers in rainy weather.
- Use natural or constructed means (e.g., green roofs, rain barrels, cisterns) to harvest rainwater.

In addition, **water utilities** can play a role by taking the following actions:

- Assess the vulnerability of water systems (e.g., pipes, culverts, treatment plants) to extreme events and more intense precipitation.
- Consider rate structures based on water usage to encourage conservation.

Human Health

Climate change can directly and indirectly affect vital determinants of health such as clean air, safe drinking water, sufficient food as well as secure shelter. This can include impacts from increased extreme weather events such as heat, droughts, and floods, wildfire, decreased air quality, and illnesses transmitted by food, water, and disease carriers such as mosquitoes (Luber et al. 2014). Some existing health threats will intensify, and new health threats will emerge.

Climate change is expected to cause around 250,000 additional deaths per year globally between 2030 and 2050 (WHO 2018). This includes deaths from malnutrition, malaria, diarrhea, and heat stress. There are additional direct damage costs to health from climate change, which is estimated to be around $2-4 billion per year by 2030 (WHO 2018). Taking actions such as preparedness and prevention, can help protect people from some of the impacts of climate change.

Climate Change Impacts

The expected impacts of climate change on human health in Pennsylvania (Shortle et al. 2015) include:

- Increased heat-related illness and mortality due to higher temperatures, particularly during intense heat waves affecting older populations and those with existing conditions such as asthma and heart disease.
- Increased distribution and prevalence of Lyme Disease, West Nile Virus, and Zika Virus due to changing distribution of pests due to changing temperature and precipitation. Uncertain impacts on vectors and tick-borne diseases and life cycles are factors.
- Increased respiratory and heart disease rates due to declining air quality.
- Increased health risks due to contact with polluted water, since higher temperatures, algal blooms, and other factors could reduce water quality in streams and lakes.
- Increased risk of injury and death due to extreme weather events (e.g., non-tropical extreme rainfall, flooding, etc.) exacerbated with climate change.
- Increased allergens due to changing temperatures and seasonality.

Opportunities to Reduce Emissions and Adapt to Climate Change

In the Human Health sector, DEP has identified two main strategies to reduce emission and adapt to climate impacts:

- **Improve reliability and accessibility of public information about climate-related health risks**
- **Bolster emergency preparedness and response**

Each strategy description below includes leadership, citizen, and business actions that support the strategy; a summary of strategy benefits and costs; and key performance indicators.

The team did not quantitatively analyze these actions.

Improve Reliability and Accessibility of Public Information about Climate-related Health Risks

Research is limited on exactly how climate change may affect human health in Pennsylvania. Additional information is needed to better understand climate-related health trends, and ensure that the public has the information it needs to take necessary precautions.

Leadership Actions

It is important to improve the understanding of climate impacts to health in Pennsylvania through monitoring and data collection. For example, leaders can:

- Support efforts to develop new surveillance databases and increase data quality and availability, especially for climate-sensitive morbidity.
- Update Community Health Assessments to include climate change and health tracking metrics.

Working with medical professionals will help contextualize these issues, and determine and communicate the risks facing public health. Leaders can:

- Increase interdisciplinary collaboration among medical and health professionals and other environmental and social scientists to better understand the linkage between climate change and disease.
- Help local health departments assess their capacity to respond to health threats and to integrate climate preparedness into their hazard response plans and daily operations.
- Enhance education of health-care professionals to understand the health risks of climate change, including diagnosis and treatment for health outcomes that may become more prevalent.

Additionally, state and local leaders can inform the public about the potential health risks due to climate change. Leaders can develop a web-based resource hub to provide information and technical resources, incorporate climate change and public health messages into existing education and outreach efforts, and expand public outreach and education efforts about climate-related health risks.

Climate impacts to health are likely to have disproportionate impacts on vulnerable communities. State and local governments must recognize these impacts and act to reduce these impacts. For example, leaders can:

- Work locally with vulnerable groups to assist at-risk communities with the development, adoption, practice, and evaluation of response, evacuation, and recovery plans.
- Regularly map locations of vulnerable populations and use the information to focus interventions and outreach.
- Review occupational health and safety standards to identify occupations at significant risk due to climate change, and revise as necessary.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

The climate resilience benefits of improved reliability and accessibility of public information about climate-related health risks include:

- Reduced illness and mortality associated with heat, vector-borne diseases, and water-borne diseases
- Increased capacity to manage the incidence of vector-borne disease
- Protection of vulnerable communities from disproportionate climate impacts

Economic Benefits & Costs

Additional modeling would be necessary to quantify benefits, but reductions in morbidity and mortality provide a significant economic benefit. In addition, improved data reliability and awareness of climate-related health risks could increase the quality or efficiency of health care services and reduce costs in the healthcare sector. For example, it could increase the number of patients able to seek early treatment, or improve physicians' ability to diagnose and care for patients with climate-related ailments.

Key Performance Indicators

Example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Heat-stress related emergency department visits
- Hospitalizations due to climate-related impacts
- Heat-related mortality
- Participation in public outreach and education events
- Cases of Lyme Disease and other vector-borne illnesses
- Injuries and deaths from extreme weather events

What You Can Do to Improve Reliability and Accessibility of Public Information about Climate-related Health Risks

Pennsylvania citizens can support this strategy by taking the following actions:

- ► Know the symptoms of heat-related illness and take care to stay cool on hot days–wear loose-fitting, light-colored clothing, minimize direct exposure to the sun, and stay hydrated.
- ► Check the local news for health and safety updates. Subscribe to local heat alert systems, such as AlertPA.
- ► Use air conditioning or spend time in air-conditioned places, such as cooling centers, malls, and libraries when outdoor temperatures are extremely high.
- ► Use electric fans to provide comfort when the temperature is below 95 degrees F. Fans can improve evaporation to help heat leave the body. However, above 95 degrees F, fans are insufficient.
- ► Get involved in workplace, schools, and organizations to ensure that committees are in place to develop a heat response plan and take proper measures for those participating in outdoor work or activities.
- ► Shorten work periods and increase rest periods as temperature and humidity rises. Choose shaded rest areas (find more details on heat-related adaptation strategies for workers from the Occupational Safety and Health Administration (OSHA) available at: https://www.osha.gov/SLTC/heatillness/heat_index/work_rest_schedules.html).

- Prevent mosquito bites to protect yourself from mosquito-borne diseases, such as Zika, West Nile Virus, malaria, etc. (see CDC Guidance available at https://www.cdc.gov/zika/prevention/prevent-mosquito-bites.html).
- Prevent tick bites to protect yourself from tick-borne illnesses, which might become more prevalent due to climate change (see CDC Guidance available at https://www.cdc.gov/ticks/avoid/index.html).

What Businesses Can Do to Improve Reliability and Accessibility of Public Information about Climate-related Health Risks

The Pennsylvania **healthcare industry** can support this strategy by taking the following actions:

- Expand analytical laboratory capacity to support essential environmental monitoring, disease surveillance, and outbreak investigation and control activities.
- Enhance prevention (e.g., vaccination) and treatment capabilities.
- Assign more medical staff at places where people congregate and recreate in hot weather and may suffer heat stress.

Bolster Emergency Preparedness and Response

Climate change is expected to increase the frequency and intensity of extreme events, including floods, extreme heat, and disease outbreaks. Pennsylvania can reduce the impacts of these events by continuously improving its preparedness for emergency situations and developing thorough response plans that take climate impacts into account.

Leadership Actions

Pennsylvania leaders can prepare for emergency situations by incorporating climate change considerations into planning. For example, leaders can:

- Review existing emergency response, preparedness, evacuation, and management plans to ensure that events that will become more likely with climate change are adequately addressed; to address the most updated estimates of likely levels of precipitation, flooding, and extreme storm events; and to include coordination and communication among critical stakeholders, such as community organizations, local businesses, local health departments, hospitals, and other health-care delivery facilities, utilities, and local government.
- Expand the scope of the state hazard mitigation plan to factor in expected vulnerabilities from climate change impacts.

Additionally, state and local leaders can prepare communities to deal with disasters by evaluating current practice, establishing early warning systems, improving response capability, and conducting outreach. Specific actions include the following:

- Evaluate and improve the adequacy, effectiveness, accuracy, and technological capabilities of forecasting, early-warning, and emergency-preparedness systems.
- Foster collaboration between communication service providers and agencies to provide reliable communications in times of power outages and emergencies.

- Establish heat advisories, increase availability of cooling stations, invest in efficient HVAC systems at targeted Recreation Centers which are provided with renewable energy backup systems, and implement other preventive measures to reduce the impact of extreme heat events.
- Evaluate the capacity of existing disease prevention programs, enhance surveillance of disease and disease-causing agents, and enhance the capacity of public health programs that control disease-causing agents.
- Restructure disaster-recovery policies to ensure that redevelopment efforts strive to reduce long-term risk.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

The climate resilience benefits of bolstering emergency response include:

- Improved capacity to respond to emergency situations.
- Reduce injury and mortality risk due to extreme weather events.
- Reduced heat-related morbidity and mortality.
- Reduced impacts of vector-borne diseases which are expected to become more commonplace due to climate change.

Environmental Benefits & Costs

Emergency preparedness and response can help protect the environment from negative impacts, including pollution. During extreme events, wastewater treatment plants, chemical plants, and oil and natural gas facilities may experience flooding. If not prepared, these floodwaters can produce leaks and flows of toxic materials into waterways, presenting a health risk for ecosystems and humans. In the past, power outages due to extreme events have contributed to the discharge of raw sewage, which often contains disease-causing organisms, heavy metals, and excessive nutrients (EPA 2018a, NEIWPCC 2016). Wastewater is hazardous to the environment, particularly water quality and soil contamination (NH DES 2015). Oil and natural gas operations, both extraction and processing, could be impacted by extreme weather events and preparedness can help mitigate negative environmental impacts of these events.

Economic Benefits & Costs

A National Institute of Building Sciences study of federally funded disaster mitigation grants found that every dollar invested in disaster mitigation saves the country six dollars in future disaster costs (National Institute of Building Sciences 2017). Between 2012 and 2016, Pennsylvania spent $17,462,000 on natural disaster programs (PEW 2018). Due to storms and flooding in 2016, Pennsylvania experienced damages to roads and bridges equivalent to $33,202,883 and received a grant for $27,323,547 from the Federal Emergency Management Agency (FEMA) for recovery efforts (FEMA 2016). Bolstering disaster preparedness and response will help avoid costs due to damaged infrastructure, loss of life, and human injuries.

Key Performance Indicators

Example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Number of people reached through emergency-related communications and stakeholder outreach
- Facilities with least impact backup power generation, and if needed, how many of these systems worked
- Drills and simulation exercises held to test emergency protocol
- Inventory system for essential supplies and equipment
- Time required for emergency response

What You Can Do to Bolster Emergency Preparedness and Response

Pennsylvania citizens can support this strategy by taking the following actions:

- ► Subscribe to emergency text alert services from government officials.
- ► Ensure a supply of water in the house, in case of emergency. FEMA recommends keeping a three-day supply of water available in case clean water is not available.
- ► Keep extra batteries and a car charger for your mobile devices. This will allow you to stay up-to-date on news reports and use your phone to stay in touch with friends and family. If you use your car to charge your devices, make sure it's in a well-ventilated place.
- ► Keep a physical list of emergency, family, and work contacts. In case your phone battery dies, you could find a landline to check on friends and loved ones.
- ► Know the location of flashlights and a radio. Make sure these things are easy to access in case of power loss, and that you have extra batteries to keep them running.
- ► During extreme events, conserve your cell phone battery. Reduce the brightness of your screen, place your phone in airplane mode, and close unused apps that draw power.
- ► Prevent overloaded circuits. Switch off all unnecessary lights and appliances to prevent overloaded circuits when power is restored.
- ► Keep your car tank at least half full. Gas stations rely on electricity to power their pumps.

What Businesses Can Do to Bolster Emergency Preparedness and Response

Pennsylvania businesses can support this strategy by taking the following actions:

- ► Ensure that your business has an emergency response plan.
- ► Prepare employees to evacuate and respond in the case of an emergency.
- ► Install least impact backup power generation capacity to maintain critical operations.

Cross-Cutting Opportunities to Reduce Emissions and Adapt to Climate Change

Pennsylvania has several opportunities to adapt to climate change that are not limited to a single sector. These cross-cutting opportunities span all activities in the commonwealth, and fall into two high-level strategies:

- **Lead by example in commonwealth and local government practices and assets**
- **Incorporate historical and projected climate conditions into siting and design decisions for long-term infrastructure**

Lead by Example in Commonwealth and Local Government Practices and Assets

The commonwealth and local governments can take a leading role in developing a more sustainable and resilient Pennsylvania by taking action and demonstrating best practices in government operations and projects.

Leadership Actions

Below are examples of the ways in which state and local governments can demonstrate the importance and feasibility of climate adaptation and reducing emissions, showing that they are committed to climate action and setting an example for the rest of the commonwealth. Actions in italics are identified in Executive Order 2019-1, signed by Governor Wolf on January 8, 2019, which also sets a statewide climate goal for Pennsylvania of 26 percent reduction of net greenhouse gas emissions statewide by 2025 from 2005 levels, and an 80 percent reduction of net greenhouse gas emissions by 2050 from 2005 levels. Specific Performance Goals for all Commonwealth Agencies are in Bold (See www.oa.pa.gov/Policies/eo/Documents/2019-01.pdf).

- Establish a strategic energy management plan for public facilities that includes benchmarking and specific energy, water, and transportation emissions reductions targets and goals. ***Collectively reduce overall energy consumption by 3 percent per year, and 21 percent by 2025 from 2017 levels.***
- Maximize onsite renewable energy generation and purchase additional renewable power through renewable energy certificates (RECs) or direct purchasing. ***Procure renewable energy to offset at least 40 percent of the Commonwealth's annual electricity use and evaluate opportunities to source electricity through Pennsylvania Certified Tier I credits, and/or direct purchase of renewable power generation sited within Pennsylvania.***
- Implement a state-wide benchmarking strategy and platform (such as EnergyStar's Portfolio Manager) for energy and water consumption. Engage the PUC and PA's gas, electric and water utilities to automate billing and utility data input into the selected benchmarking platform, and encourage others (businesses, industry, schools, and municipalities) to implement similar programs to establish their baseline consumption patterns. *DGS will work with all agencies to track and analyze agency utility bills through Pennsylvania's utility bill management system.*

- Establish a state-wide Governor's Sustainability Council and/or interagency workgroup dedicated to the implementation of leadership actions listed in the CAP, as well as actions in department-level plans. *Governor Wolf reestablished the Governor's Green Government Council, to encourage the incorporation of environmentally sustainable practices into the Commonwealth government's policy, planning, operations, procurement, and regulatory functions, and strive for continuous improvement in efficiency and performance.*
- Incorporate climate change considerations into decision making processes and criteria. For example, add climate change resilience as a prioritization factor for new capital projects.
- Consider ENERGY STAR certification for existing buildings, and Architecture 2030, LEED, net-zero designs, and climate resilience design guidelines to drive higher performance in new construction and major renovation projects in public buildings. ***Any new building construction project, build-to-suit leased building, or renovation project by a Commonwealth agency that costs more than 50 percent of the replacement cost of the building, where the design of the project commences after the effective date of the Executive Order, shall be designed and constructed as a high-performance building achieving a 10 percent reduction in energy consumption over ANSI/ASHRAE/IES Standard 90.1.2016. Agencies may seek US Green Building Council LEED certification, Green Building Initiative Green Globe rating, or a comparable numeric rating from another accredited sustainable building certification program where appropriate.***
- Inventory and benchmark state and local government buildings' energy use patterns, using tools such as Portfolio Manager and supporting analytics, to identify savings opportunities. *Pennsylvania Department of General Services (DGS) will benchmark Commonwealth facilities' energy efficiency against federal and association standards.*
- Implement emissions reduction and climate resilience activities in public facilities, including distributed generation, backup power generation, water efficiency, climate resilient vegetation, and proper tree maintenance. *DGS will coordinate with all agencies to include green building, energy conservation, and energy efficiency practices as part of any new construction and renovation projects.*
- Require energy efficient and alternative fuels use in fleet vehicles and equipment. ***Replace 25 percent of the state passenger car fleet with battery electric and plug-in electric hybrid cars by 2025 and evaluate opportunities for the reduction of vehicle miles traveled and incorporation of new technology where appropriate.***
- Conduct more training, education, and outreach on energy efficiency, clean energy, climate resilience, and related skills for facility managers and the facility management workforce. *DGS will develop and implement programs to train appropriate personnel in benchmarking, energy conservation, and energy efficiency.*
- Ensure that key government operations plan for and provide least impact energy backups to protect important security features in the case of more frequent or prolonged blackouts. For

example, the Pennsylvania Army National Guard is building a solar farm on its largest military base to have its own backup power.

- Highlight climate action already occurring in Pennsylvania and learn from best practice examples within and outside the commonwealth.

Strategy Benefits and Costs

Resilience Impacts

Benefits of leading by example in adaptation include:

- Increased resilience of public services to floods, power outages, heat waves, droughts, and other disruptive events.
- Reduced overall costs to government in the form of infrastructure maintenance, operations, energy costs, and emergency response.
- Expanded capacity of Pennsylvania citizens and businesses to increase their own resilience to such events.

Environmental Benefits & Costs

This strategy incorporates many of the aspects of other strategies identified in this report; therefore, it offers many of the same environmental benefits such as reduced GHG emissions, reduced air pollution, and reduced health risks.

Economic Benefits & Costs

This strategy incorporates many of the aspects of other strategies identified in this report; therefore, it offers many of the same economic benefits such as reduced energy expenditures.

Key Performance Indicators

Example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Government operation GHG emissions
- LEED, ENERGY STAR, and other certified buildings owned or leased by the government
- Share of the government fleet that is alternative fuel or zero emission vehicles
- Reduction in VMT by government fleets
- Energy efficiency guidelines met by new construction, or number of net zero energy buildings
- Water and energy consumption reduced through conservation and efficiency

Incorporate Historical and Projected Climate Conditions into Siting and Design Decisions for Long-term Infrastructure

When new infrastructure is built, the choice of location and design have large implications for how the system with hold up under future conditions. Given the long lifespans of some infrastructure, including buildings, bridges, roads, and power plants, it is important to consider the climatic conditions throughout the life of the project and how to ensure that the asset will remain functional and protected.

Leadership Actions

The commonwealth can use funding and regulatory tools to ensure that long-term infrastructure is built in locations that will be stable for the long-term and incorporate planning and design elements that will make them more resilient to climate impacts. For example, leaders can:

- Establish statewide design guidelines for incorporating climate change, similar to New York City's design guidelines (NYC Mayor's Office of Recovery and Resiliency 2018).
- Integrate climate change considerations into agency-level capital planning processes and seek to ensure that state investments in infrastructure and development projects (direct or indirect) reflect potential climate change impacts, especially future risk projections. For example, require project sponsors to self-identify vulnerabilities to climate change and incorporate climate change impacts into the return on investment calculations.
- Implement new or modified policies (e.g., zoning regulations, tax incentives, and rolling easements) that encourage appropriate land use and reduce repetitive losses.
- Develop or update floodplain mapping using the best available science and accounting for the impacts of climate change.
- Adopt insurance mechanisms and other financial instruments, such as catastrophe bonds, to protect against financial losses associated with infrastructure losses.
- Encourage owners and operators of critical energy infrastructure to evaluate vulnerability to the impacts of climate change, including the risk of damage; the potential for disruptions and outages from flooding, sea level rise, extreme heat, drought, erosion and other extreme weather events; and the impacts of new climate change weather data on energy demand.

Strategy Benefits and Costs

Climate Resilience Benefits & Costs

The climate resilience benefits of incorporating climate considerations into siting, design, and system planning include:

- Reduced exposure of infrastructure to extreme events and flooding, which reduces costs associated with recovery from repetitive losses and ensures continued infrastructure services (e.g., energy, water, and transportation) even during climate extremes.
- Ensured reliability of critical systems (e.g., transportation, energy, water, and communications) into the future.
- Ensured continuity of operations for the numerous businesses, individuals, and activities dependent on critical services (e.g., transportation networks, electric power).
- Reduced costs to energy utilities and consumers.

Environmental Benefits & Costs

Incorporating climate projections into infrastructure design can help reduce the impact of flooding and damage related to severe weather events. Landslides, mudslides, erosion, and sedimentation, to name a few, can result from extreme weather events that lead to damages to roads, bridges, and other infrastructure. In the case of severe weather, infrastructure debris could become pollutants in the

environment, such as bridge components washed downstream. Also, there is an environmental cost associated with rebuilding. Extreme events could also contribute to destruction of wildlife habitat and species kills, such as stocked fish being swept downstream in a storm.

Economic Benefits & Costs

Overall economic benefits and costs of this strategy are unknown. Some changes to infrastructure design to accommodate expected climate change could increase the upfront costs of capital projects. However, ignoring the climate changes could potentially result in much higher costs, in the form of higher operating costs, business disruptions, or infrastructure damage. Individual projects should consider the future frequency of extreme events in their estimates of the return on investment for that project.

Key Performance Indicators

Example indicators that Pennsylvania could use to measure progress toward this strategy include:

- Design standards incorporating climate projections
- Length of infrastructure service disruptions

What You Can Do to Incorporate Historical and Projected Climate Conditions into Siting and Design Decisions for Long-term Infrastructure

Pennsylvania citizens can support this strategy by taking the following actions:

- ► Understand risks to your property.
- ► Consider purchasing flood insurance, even if you are not required to do so.
- ► Encourage your state and local leaders to invest in climate-resilient public infrastructure.
- ► Encourage leaders to incorporate climate change into energy, transportation, and communications system planning.
- ► Participate in long-range planning processes with your local government or public utility commission.

What Businesses Can Do to Incorporate Historical and Projected Climate Conditions into Siting and Design Decisions for Long-term Infrastructure

Pennsylvania businesses can support this strategy by taking the following actions:

- ► Understand risks to your property.
- ► Ensure sufficient availability of least impact backup power at all critical sites.
- ► Conduct vulnerability assessments of potential and existing critical infrastructure at risk of climate impacts including higher temperatures, water scarcity, and sea level rise.
- ► Protect critical, vulnerable infrastructure as appropriate based on vulnerability assessments, and, when necessary, relocate.

Engineers and Architects can support this strategy by taking the following actions:

- ► Stay abreast of industry guidance on how to create climate-resilient infrastructure.
- ► Consider climate conditions over the lifetime of the asset when designing new infrastructure.
- ► Design buildings to be more flexible. For example, use modular buildings that can be moved, renovated, and deconstructed easily. Design buildings for passive survivability (without external power).

The **Electricity Sector** can support this strategy by taking the following actions:

- Develop and implement drought-resistant cooling technologies to reduce the curtailments drought could cause at nuclear, coal, and natural gas power plants, potentially affecting electric grid reliability.
- Explore opportunities to coordinate water treatment and energy generation. For instance, locating power plants next to wastewater treatment facilities could partly displace freshwater needs for cooling purposes.
- Develop operational contingency plans for critical infrastructure, including energy supply and distribution networks.
- Enhance the climate resilience of electric grid and communications infrastructure (e.g., towers, lines) in coastal and inland flood zones.
- Monitor and model temperature and precipitation patterns to understand how changing weather patterns will affect hydropower generation in both drought and flood situations. Monitor instream flows in basins with thermal and hydropower generation facilities.
- Seek to reduce water use in energy production by considering alternative technologies since peak water use in energy production often coincides with periods of high heat and low water availability.
- Review equipment specifications to ensure adequacy under future climate conditions.
- Replace outdated turbines and generators with more efficient equipment at hydropower facilities to generate more electricity per unit of water and generate more efficiently across a range of flow conditions.
- Alter the timing of hydropower generation to more closely mimic a river's natural ebb and flow.

Recommendations for Further Research

Many climate change-related topics are complex and evolving, requiring more in-depth analysis to inform further decision making.

Leadership Actions

The Commonwealth of Pennsylvania will need to further research several topics over time to inform decision making. For example, leaders can:

- Conduct a statewide comprehensive climate change risk assessment that builds off the current climate impacts assessment, but allows for prioritization across sectors, geographies, and strategies.
- Assess the potential impacts of policies and programs that make carbon dioxide and other GHGs as tradable commodities in more detail than the analysis underlying this report.
- Identify and evaluate specific policy options for maintaining and/or restoring nuclear electric power capacity.
- Study the potential impacts of the use of carbon capture, utilization, and sequestration on the commonwealth.

4 Benefits and Costs for Modeled Strategies and Actions

This section summarizes the benefits and costs of the 15 quantitatively analyzed actions within the seven quantified strategies. Notably, these actions represent only a subset of the potential actions under a subset of the identified strategies. In other words, the benefits and costs in this section do not comprehensively account for all the strategies and actions identified in this Plan due to resource and time constraints. If Pennsylvania pursues actions and strategies beyond those that were quantitatively assessed, there would be additional benefits and costs that are not quantified in this analysis from reducing GHG emissions and adapting to climate change. In addition, if the commonwealth pursues the quantified strategies and actions in a different way than the team's assumptions, the benefits and costs will differ from this analysis.

Figure 12 illustrates how each of the seven strategies, grouped by sector (Energy Consumption, Energy Production, and Agriculture) contributes to progress towards reaching the GHG reduction targets selected for modeling in this Plan.

- Total annual GHG reductions in 2025 resulting from the quantified strategies are **39,435,490 MTCO$_2$e**, which, when combined with the decreasing trend in annual BAU emissions, results in a 21 percent reduction from 2005 levels. This falls short of the target set forth for modeling purposes: a 26 percent reduction from 2005 GHG emission levels by 2025. In 2025 GHG reduction contributions from each sector are:
  - Energy Consumption-related annual GHG reductions are **6,889,187 MTCO$_2$e** (3% reduction from 2005 levels)
  - Energy Production-related annual GHG reductions are **31,391,440 MTCO$_2$e** (12% reduction in energy consumption emissions and 6% reduction in energy production emissions from 2005 levels)[15]
  - Agriculture-related annual GHG reductions are **208,331 MTCO$_2$e** (3% reduction from 2005 levels)[16]
- Total annual GHG reductions in 2050 resulting from the quantified strategies are **87,439,278 MTCO$_2$e**, which, when combined with the decreasing trend in annual BAU emissions,

[15] Emission reductions from strategies that affect the electricity generation fuel mix (e.g., utility scale renewable generation, nuclear generation, cap and trade) are accounted for in the energy consumption sector based on the reduction in the electricity consumption emission factor (i.e., a reduction of carbon intensity of the grid). Distributed renewable electricity generation is also accounted for as reductions to energy consumption emissions. Thus, emissions from these strategies are compared to the BAU emissions from energy consumption. Emissions reductions from coal mine methane capture and upstream oil and natural gas are accounted for in the energy production sector, so these are compared to the BAU emissions from energy production.

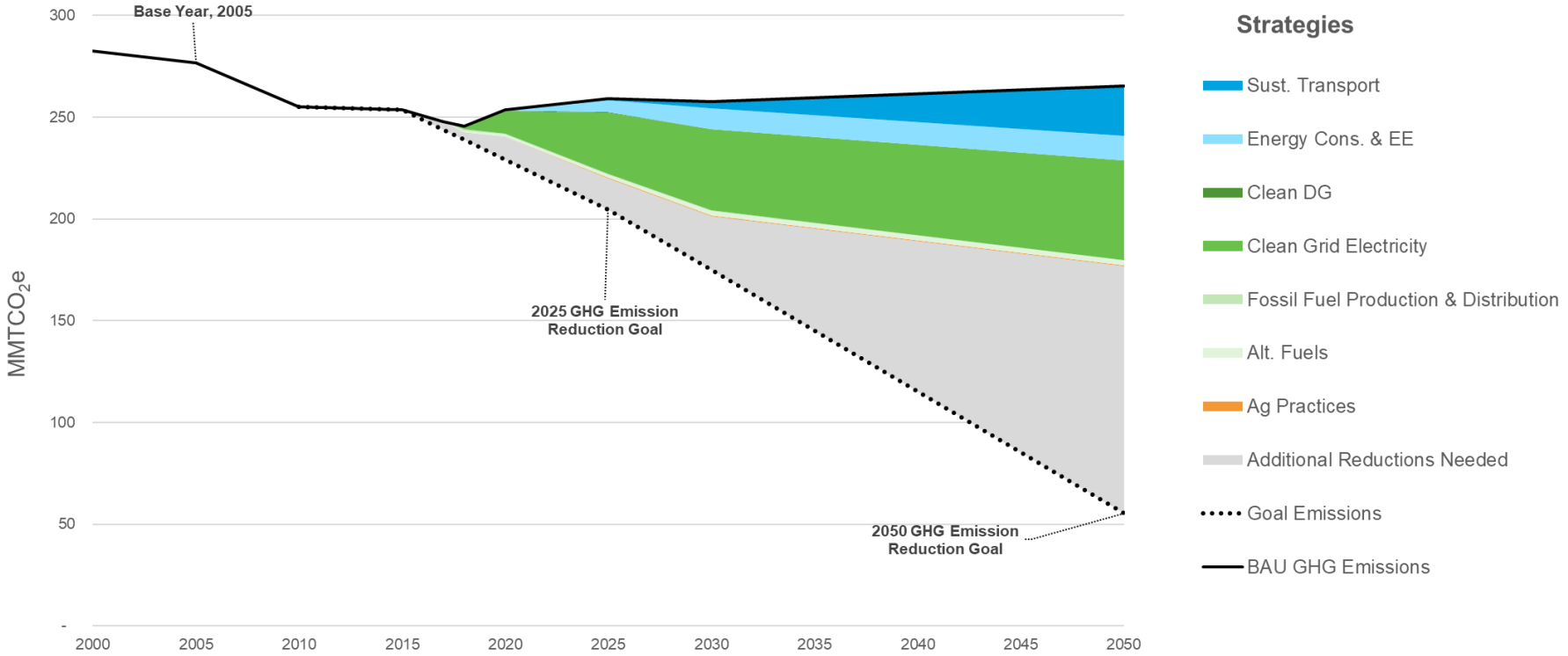
[16] This includes some emission reductions from energy consumption due to changes in fuel consumption by agricultural equipment.

results in a 36 percent reduction from 2005 levels. This does not meet the target set forth for modeling purposes: an 80 percent reduction from 2005 GHG emission levels by 2050. In 2050 GHG reduction contributions from each sector are:

- Energy Consumption related annual GHG reductions are **37,005,093 $MTCO_2e$** (14% reduction from 2005 levels)
- Energy Production-related annual GHG reductions are **48,858,287 $MTCO_2e$** (19% reduction in energy consumption emissions and 7% reduction in energy production emissions from 2005 levels)
- Agriculture-related annual GHG reductions are **328,070 $MTCO_2e$** (4% reduction from 2005 levels)

The results for 2025 and 2050 fall short of meeting the modeling targets of 26 percent (2025) and 80 percent (2050) relative to 2005 GHG emissions. However, these findings are consistent with what other jurisdictions are seeing—actions with large GHG reduction potential, such as those quantified for this Plan, are not quite enough to meet 2025 or 2050 targets, when taken alone. For example, the America's Pledge report, *Fulfilling America's Pledge: How States, Cities, and Businesses are Leading in the United States to a Low Carbon Future,* shows that implementation of ten key climate actions—which are, for the most part, similar to what was modeled for this Plan—will likely result in a 21 percent reduction of annual GHG emissions in 2025 as compared to 2005 levels for America's Pledge, U.S. Climate Alliance, and Climate Mayors participants (America's Pledge 2018b). This finding further emphasizes the need for more ambitious and quick climate action from all actors, including leadership, businesses, and citizens. This is particularly relevant for 2025 where there is less uncertainty than 2050 and more visibility into potential implementable actions.

Figure 12. GHG Reductions Through 2050 for All Strategies, By Sector ($MMTCO_2e$)



Note: Blue shading indications emission reductions from strategies within the Energy Consumption sector; green shading indicates emission reductions from strategies within the Energy Production sector; and orange shading indicates emission reductions from strategies within the Agriculture sector. For wedges that are relatively smaller in size, Figure 13 *and Figure* 14 *provide a different graphical representation of reductions.*

Figure 13 and Figure 14 show the GHG emissions reductions of each quantified action within the seven quantified strategies in both 2025 and 2050, respectively. As seen, the strategy to create a diverse portfolio of clean, utility-scale electricity generation has the most significant emission reduction impacts in both 2025 and 2050. Large GHG reductions are seen for energy conservation and efficiency measures in both 2025 and 2050, while the benefits of sustainable transportation measures do not really come into play until after 2025. While relative reductions from the other strategies are smaller, they still play a vital role in overall GHG reductions that could be achieved by implementing this Plan.

Other key conclusions in considering these GHG results are:

- Existing clean energy and climate program policies are already driving reductions in the near-term, as evidenced by the decreasing trend in BAU GHG emissions through 2025, a 6 percent (17,376,468 $MTCO_2e$) reduction from 2005 levels. However, without additional action GHG reductions under the BAU will slow in later years as existing policies and programs phase out; in 2050 BAU GHG emissions are 4 percent (11,318,853 $MTCO_2e$) lower than 2005 levels.
- The 15 actions within the seven strategies quantitatively analyzed for this Plan significantly reduce GHG beyond the reductions in the BAU. As indicated above and in Figure 12, these strategies result in Pennsylvania falling short of the target selected for modeling in 2025 and are not enough for the commonwealth to reduce GHG emissions 80 percent by 2050. In considering these results, it is important to keep in mind:
    - As highlighted above, due to resource and time constraints, the modeling conducted for this report only focuses on a subset of strategies and actions that could reduce GHG emissions in Pennsylvania. Additional strategies and actions qualitatively addressed in this report would likely result in additional GHG reductions. For example, sequestration of carbon through forests offers a lot of potential for GHG reductions in Pennsylvania. Effective conservation and management of forests through programs such as the Nature Conservancy's Working Woodlands program can help accelerate and maintain forests as carbon sinks. This program has protected over 62,000 acres and accelerated restoration on 5,000 acres in Pennsylvania alone, with the result that almost 3.5 million tons of carbon will be sequestered over the life of the projects.
    - The results do not consider new or updated federal policies that reduce GHG emissions.
    - There are high levels of uncertainty associated with forecasting GHG emissions through 2050. Although this analysis provides single estimates of GHG emissions reductions from the quantified strategies, it would be useful to conduct sensitivity analyses that examine a range of aggressiveness for underlying modeling assumptions (e.g., market penetration rates or costs of certain technologies).

Figure 13. Annual GHG Reductions Compared to BAU in 2025 for All Quantified Strategies and Actions ($MMTCO_2e$)

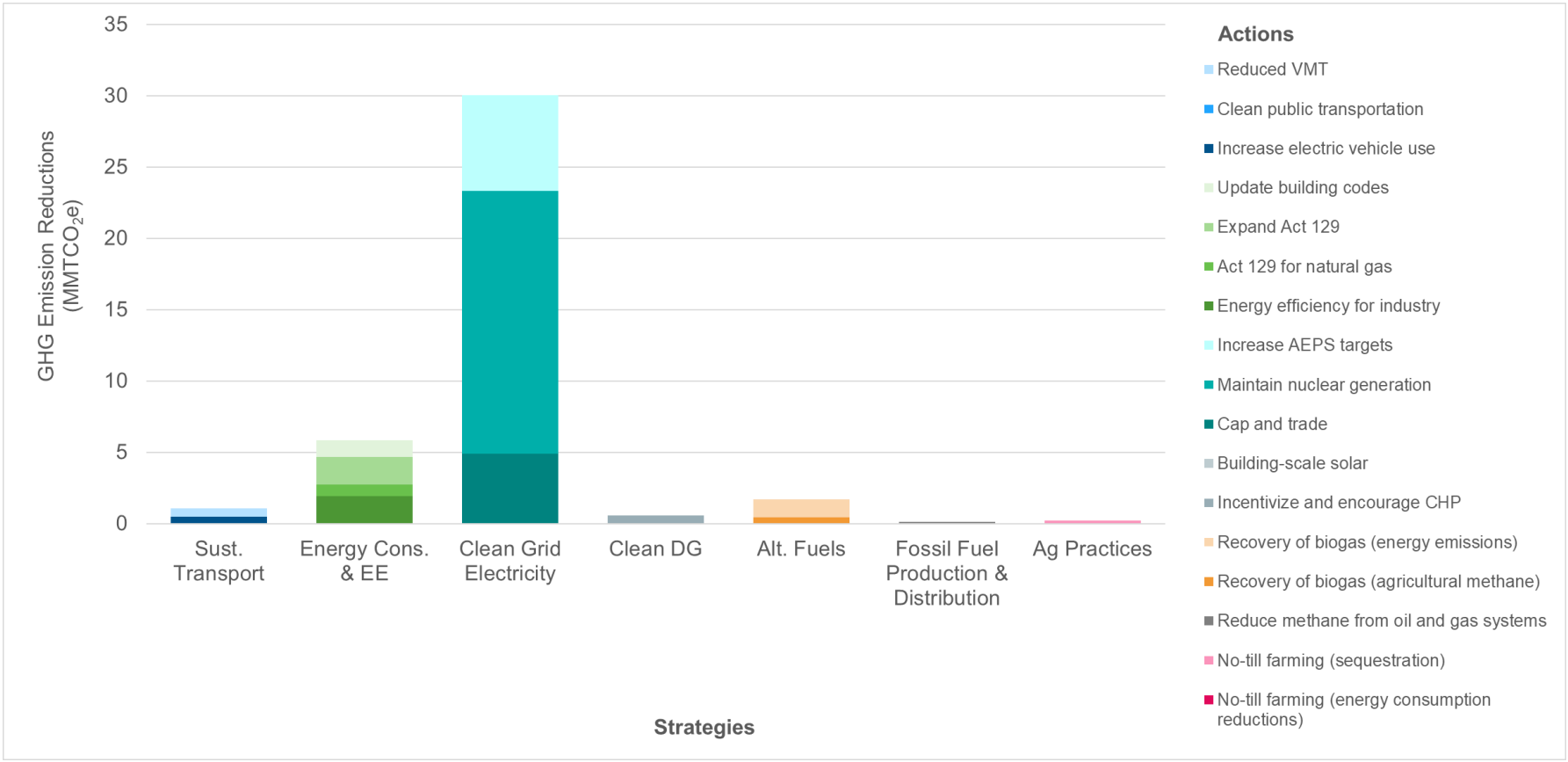
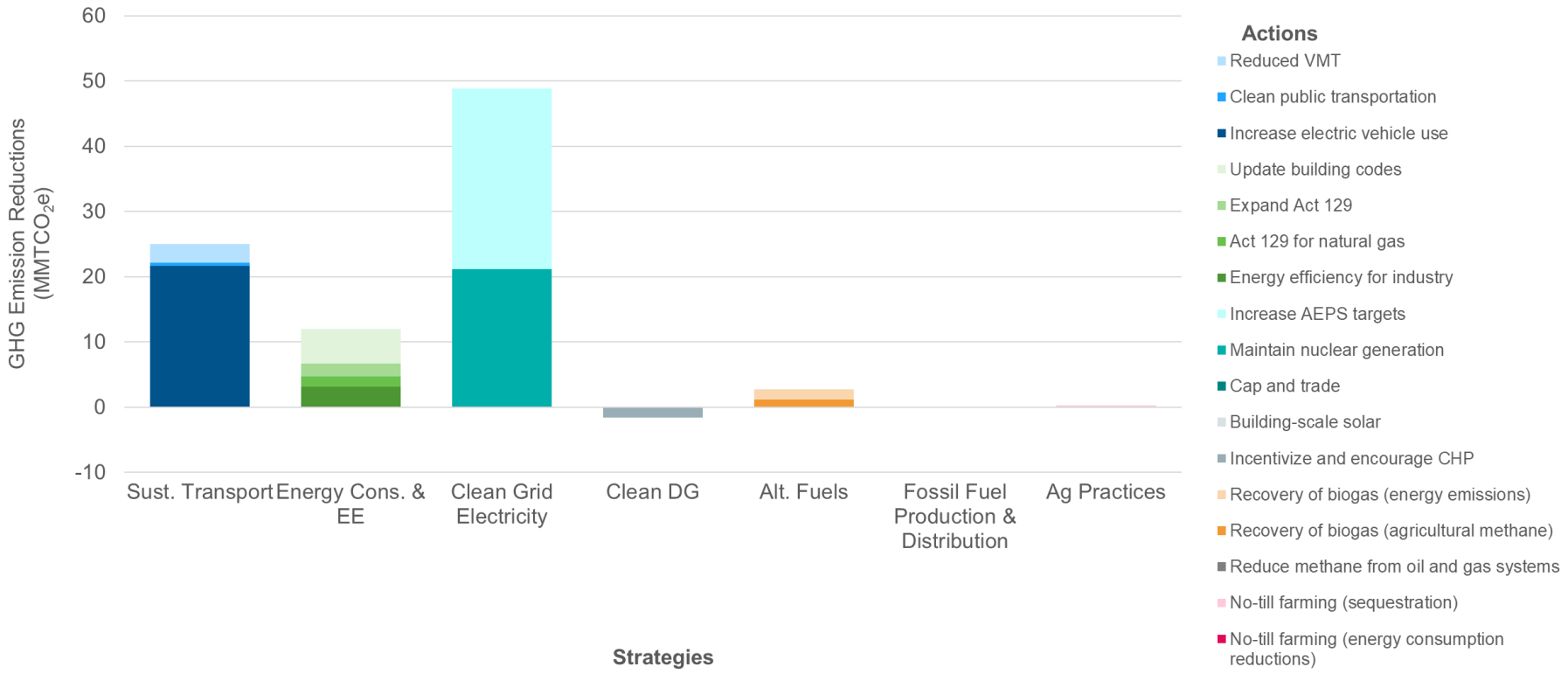


Figure 14. Annual GHG Reductions Compared to BAU in 2050 for All Quantified Strategies and Actions ($MMTCO_2e$)



Summary of Strategy-Specific Economic Benefits and Costs

To assess cost-effectiveness of the strategies presented in this report (a requirement of Act 70), DEP and the analysis team looked at multiple factors which, when considered together, can be used to understand the cost-effectiveness of a strategy. Cost-effectiveness measures assessed include:

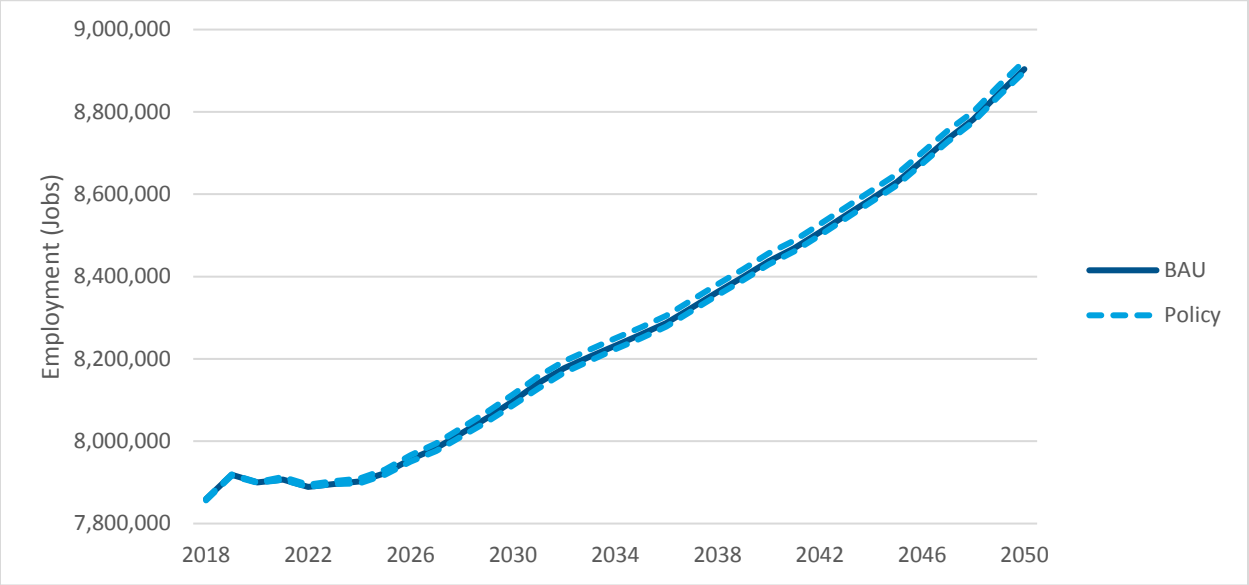
1. **Net present value (NPV),** provided for each strategy action, which is a narrow analysis of direct costs and benefits, and uses zero NPV as a benchmark. This is useful as a simple microeconomic perspective. NPV does not include externality costs, such as those of GHGs or other emissions. A negative 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.
2. **Cost per ton of CO_2e**, provided for each strategy action, which uses the social cost of carbon as a benchmark. Anything that falls below the benchmark could be considered cost-effective based on one perspective. This is useful as a climate policy perspective (see Figure 19). The Social Cost of Carbon (SCC) included in this analysis is the 2050 SCC assuming a 2.5% discount rate (EPA 2016). The EPA presents a range of SCC for 2050 between $26-$212, adding that the IPCC states the SCC estimates omit various impacts that would likely increase damages. The models used to develop SCC estimates do not currently include all of the impacts of climate change. Therefore, the $95 amount was selected for this analysis as a reasonable and accurate assumption.
3. **Macroeconomic factors** (described below), which captures multiple benefit and cost effects, including employment, gross state product, and personal income. This is useful as a richer set of indicators.

To better understand the macroeconomic impacts of the Climate Action Plan (CAP), DEP and the analysis team examined the strategies in greater detail, by estimating the impacts on employment, gross state product (GSP), and personal disposable income for commonwealth residents. As discussed in How this Plan was Developed, the analysis team utilized the REMI model to estimate these macroeconomic impacts by using individual action-level inputs to model the CAP strategies. Snapshot results from 2025 and 2050 are provided in the chapters above; this section provides a more detailed look at the macroeconomic trends.

The overall impacts of CAP strategies on the Pennsylvania economy are positive, though small in absolute magnitude.

Figure 15 shows the range of variation in total employment impacts using the largest and the smallest estimated impacts from individual strategies as the benchmarks, over the BAU projections. The trend lines appear to overlap because the total employment impacts of the CAP are small when compared to the statewide economy. While these impacts may be small, the net impacts of the CAP are positive (see Table 8 and Table 9, and net impact trend lines of Figure 16, Figure 17, and Figure 18). The transitions from strategies modeled for this Plan are not disruptive for the overall economic trajectory of the state, and offer potential additional economic benefit to the commonwealth over the BAU scenario.

Figure 15. Overall BAU Employment Compared to Policy Case Employment in Pennsylvania[1]



[1] *Employment data are from REMI. These REMI data may differ from other employment figures and projections (e.g., employment data from the Bureau of Labor Statistics) because REMI includes part time jobs in employment figures.*

Strategy-specific benefits and costs of each of the seven strategies are summarized quantitatively analyzed below. Table 8 and Table 9 provide an overall summary of strategy-level net economic impacts, both as annual averages and as cumulative impacts over the entire modeling period.

Table 8. Annual (2025 and 2050) and Cumulative (2018-2050) Number of Jobs Supported

Strategies Included in Quantitative Modeling	Annual Number of Jobs Supported (2025)	Annual Number of Jobs Supported (2050)	Cumulative Number of Job-Years [1] Supported (2018-2050)
Increase end use energy conservation and efficiency	**8,690 (0.11%)**	**19,790 (0.22%)**	**475,000 (0.17%)**
Implement sustainable transportation planning and practices	**-4,020 (-0.05%)**	**8,390 (0.09%)**	**35,380 (0.01%)**
Increase use of clean, distributed electricity generation resources	**3,610 (0.05%)**	**15,130 (0.17%)**	**362,910 (0.13%)**
Create a diverse portfolio of clean, utility-scale electricity generation	**-2,490 (-0.03%)**	**-6,210 (-0.07%)**	**-200,440 (-0.07%)**
Reduce impacts of fossil fuel energy production and distribution	**10 (0.00%)**	**-10 (0.00%)**	**-190 (0.00%)**

Strategies Included in Quantitative Modeling	Annual Number of Jobs Supported (2025)	Annual Number of Jobs Supported (2050)	Cumulative Number of Job-Years [1] Supported (2018-2050)
Increase production and use of alternative fuels	230 (0.00%)	4,020 (0.05%)	71,290 (0.03%)
Use agricultural best practices	470 (0.01%)	-500 (-0.01%)	-8,020 (0.00%)
Net Total[2]	6,500 (0.08%)	40,610 (0.46%)	735,900 (0.27%)

[1] *This the cumulative number of years newly created jobs are held through 2050.*

[2] *Each of the strategies were designed, included in the quantitative modeling, and analyzed independently in REMI. The net totals do not include interaction macroeconomic effects that would likely result from strategies implemented concurrently.*

Table 9. Annual (2025 and 2050) and Cumulative (2018-2050) Impact on Gross State Product[1] ($ Million)

Strategies Included in Quantitative Modeling	Annual Impact on GSP ($ Million) (2025)	Annual Impact on GSP ($ Million) (2050)	Cumulative Impact on GSP ($ Million) (2018-2050)
Increase end use energy conservation and efficiency	$700 (0.08%)	$1,560 (0.11%)	$37,180 (0.14%)
Implement sustainable transportation planning and practices	-$260 (-0.03%)	$1,560 (0.11%)	$15,860 (0.06%)
Increase use of clean, distributed electricity generation resources	$20 (0.00%)	$710 (0.005%)	$14,900 (0.06%)
Create a diverse portfolio of clean, utility-scale electricity generation	-$260 (-0.03%)	-$190 (-0.01%)	-$13,060 (-0.05%)
Reduce impacts of fossil fuel energy production and distribution	$0 (0.00%)	$0 (0.00%)	-$20 (0.00%)
Increase production and use of alternative fuels	$10 (0.00%)	$130 (0.01%)	$2,540 (0.01%)
Use agricultural best practices	$0 (0.00%)	-$10 (0.00%)	-$130 (0.00%)
Net Total[2]	$200 (0.02%)	$3,760 (0.26%)	$57,300 (0.22%)

[1] *GSP results are discounted at 1.75%. Numbers are rounded.*

[2] *Each of the strategies were designed, included in the quantitative modeling, and analyzed independently in REMI. The net totals do not include interaction macroeconomic effects that would likely result from strategies implemented concurrently.*

Table 8 and Table 9 show that, in total, the strategies modeled for macroeconomic impacts in this analysis show small but positive effects on total Pennsylvania jobs and gross state product, growing total jobs by over 40,000 and the commonwealth's economy by almost $4 billion. The subsections that follow provide additional detail on each strategy's modeled impacts.

Increase end use energy conservation and efficiency

Investments in end-use energy efficiency for the residential, commercial, and industrial sectors drive economic growth through several different mechanisms. Households and businesses reduce their energy consumption through the installation of energy efficient appliances, building insulation, and conservation methods. These changes in consumption reduce their monthly electricity bills. Electricity bill savings correspond to more disposable income (Figure 18) for the residential sector, and lower costs of doing business and increases competitiveness for the commercial and industrial sectors.

The economic impacts from energy efficiency are often muted initially, as the upfront investments offset some of the gains, assuming a finite (constant) budget. The trend lines in the figures below show increasing positive impacts over time as the bill savings continue to accrue and energy consumers spend those savings on other goods and services generating additional economic benefits.

The employment benefits largely relate to the installation of energy efficiency equipment (e.g., demand for electricians rises), and these increases continue as more energy efficiency investments take place. The retail sector also sees an increase in demand as sales of energy efficient appliances increase.

Implement sustainable transportation planning and practices

The macroeconomic results of sustainable transportation are primarily driven by the increasing adoption of electric vehicles. The shift to electric vehicles necessitates large capital investments for the manufacturing of electric engines, batteries, and charging stations. Comparatively, bus electrification and strategies to reduce vehicle miles traveled have much lower economic impacts as investments are lower.

The initial results reflect that the cost to consumers of purchasing electric vehicles that, on average, are more expensive than their alternative vehicle options (Figure 18 displays an initial negative trend). Employment and GSP results in Figure 17 and Figure 16 show initial downward trends as entities like gas stations see some negative impacts as cars transition away from gasoline to electricity.

After 2029, these negative impacts begin to reverse. This trend reversal occurs for several reasons: (1) decline of electric vehicle costs, which decreases the negative impact on consumer budgets; (2) entities like gas stations begin to have sizable electric charging infrastructure, mitigating the need for continued investments (GSP increases in Figure 16); and (3) consumers begin to see significant savings due to electricity being a cheaper energy source than gasoline (DPI increases in Figure 18). These positive impacts begin cause this strategy to reflect positive macroeconomic impacts by 2035.

Increase use of clean, distributed electricity generation resources

The increasing attention to the use of clean distributed electricity generation will result in positive macroeconomic impacts through increased distributed solar and CHP use. The installation of distributed solar for residential and commercial customers drives the creation of construction related jobs through

capital investments. The increase in solar demand will also drive increases in retail and installation services. Similar to energy efficiency, the initial employment impacts are muted due to investment costs but can be seen to increase over the longer term in Figure 17.

Investments by households and businesses will result in large reductions in electricity bills (similar to energy efficiency), as they generate behind-the-meter electricity and avoid purchasing electricity from the grid. These impacts result in more disposable income for households and lower costs for businesses (e.g., positive trend in Figure 18).

Likewise, sectors installing CHP systems also see lower energy bills and reduced costs as heat and power is produced very efficiently behind-the-meter.

Create a diverse portfolio of clean, utility-scale electricity generation

The creation of clean utility-scale generation results in some negative net macroeconomic impacts, due to its multiple effects on Pennsylvania's generation mix and related energy industries. Because this strategy has several competing components that impact the state economy in both positive and negative ways, some parts of the energy sector gain jobs while others contract. It is also worth noting that these effects are small, less than one-tenth of one percent for total employment.

The expansion of the AEPS, through increased utility-scale solar and wind generation, initially leads to the growth in renewable energy jobs in the commonwealth. Investments in solar and wind generation spurs employment growth that can be seen in the early years of Figure 17, peaking at over 6,000 jobs in 2021. The cumulative capital investment of $8.9 billion through 2025 is expected to increase total employment by around 46,000 jobs years through the same time span. Investments in renewable energy peak by 2030, and are projected to approach approximately $20 billion, resulting in close to 100,000 job-years by 2030. By the end of the modeling period (2050) the cumulative investments are estimated to be over $37 billion, and are expected to support nearly 180,000 job-years in the commonwealth for the entire time period.

Reliance on renewable energy for future expansion of the electricity sector, coupled with continued nuclear generation and the establishment of a carbon price, leads to decrease reliance on fossil generation in the commonwealth, and is expected to have a negative impact on the fossil fuel-related sectors. This movement away from fossil fuels to emissions-free renewables and nuclear energy is expected to negatively impact the coal and natural gas industries by leading to retirements of existing fossil fuel-burning plants and lowering demand for resource extraction related jobs. Moreover, the establishment of a carbon price is expected to lead to fuel-switching away from coal-based generation to less expensive and cleaner natural gas-based generation. This fuel-switching increases coal retirements, leading to some job losses in the commonwealth. Finally, the revenues generated by the carbon price (via projected allowance prices) are modeled to mitigate some of these impacts via rebates to energy consumers. Given the projections of relatively low allowance prices in our modeling (between $1 and $2 per ton across the time series), however, these recycled revenues are not large enough to mitigate the overall impacts on the fossil fuel-related sectors, leading to net negative economic impacts for this strategy.

Reduce impacts of fossil fuel energy production and distribution

The economic impacts of this strategy are very small, and not representative of measurable economic changes.

Increase production and use of alternative fuels

The macroeconomic impacts of the increase in production and use of alternative fuels show positive trends across employment (Figure 17) and GSP (Figure 16). The job impacts are generated from the manufacturing and construction of agricultural waste digesters, water digesters, and biogas generators. These small scale and onsite biogas generator installations lead to an increase in energy savings and reduced costs of doing business.

Use agricultural best practices

The annual impacts of promoting agricultural best practices are small (see the agricultural best practices trend line hover near zero in Figure 16, Figure 17, Figure 18). However, the initial investments in new agricultural machinery will result in some slim economic benefits. On the whole, however, higher operating and maintenance costs in the long-term result in some small net negative economic impacts.

Figure 16. Impact on Gross State Product Through 2050, by Strategy ($ Million)

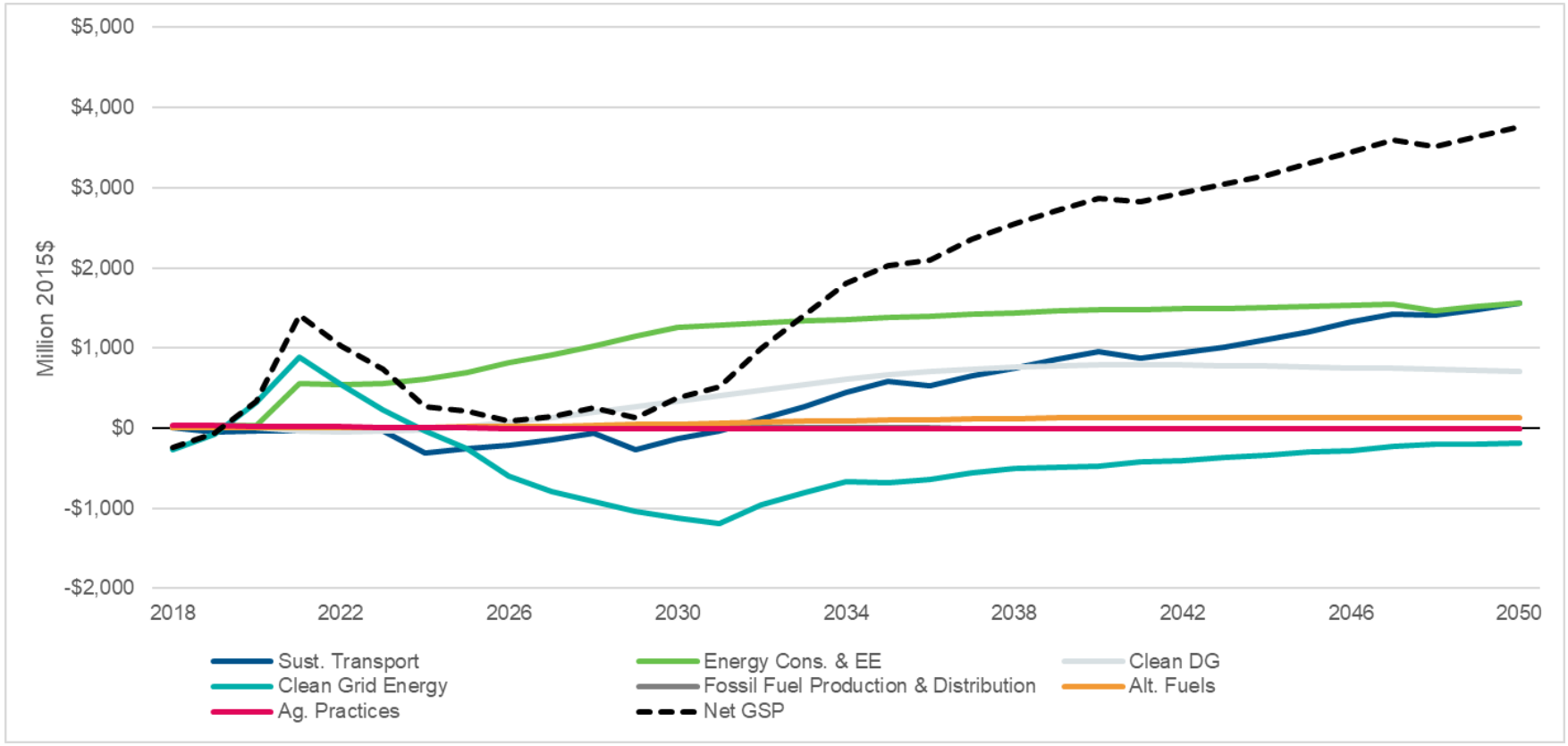


Figure 17. Number of Jobs Created Through 2050, by Strategy

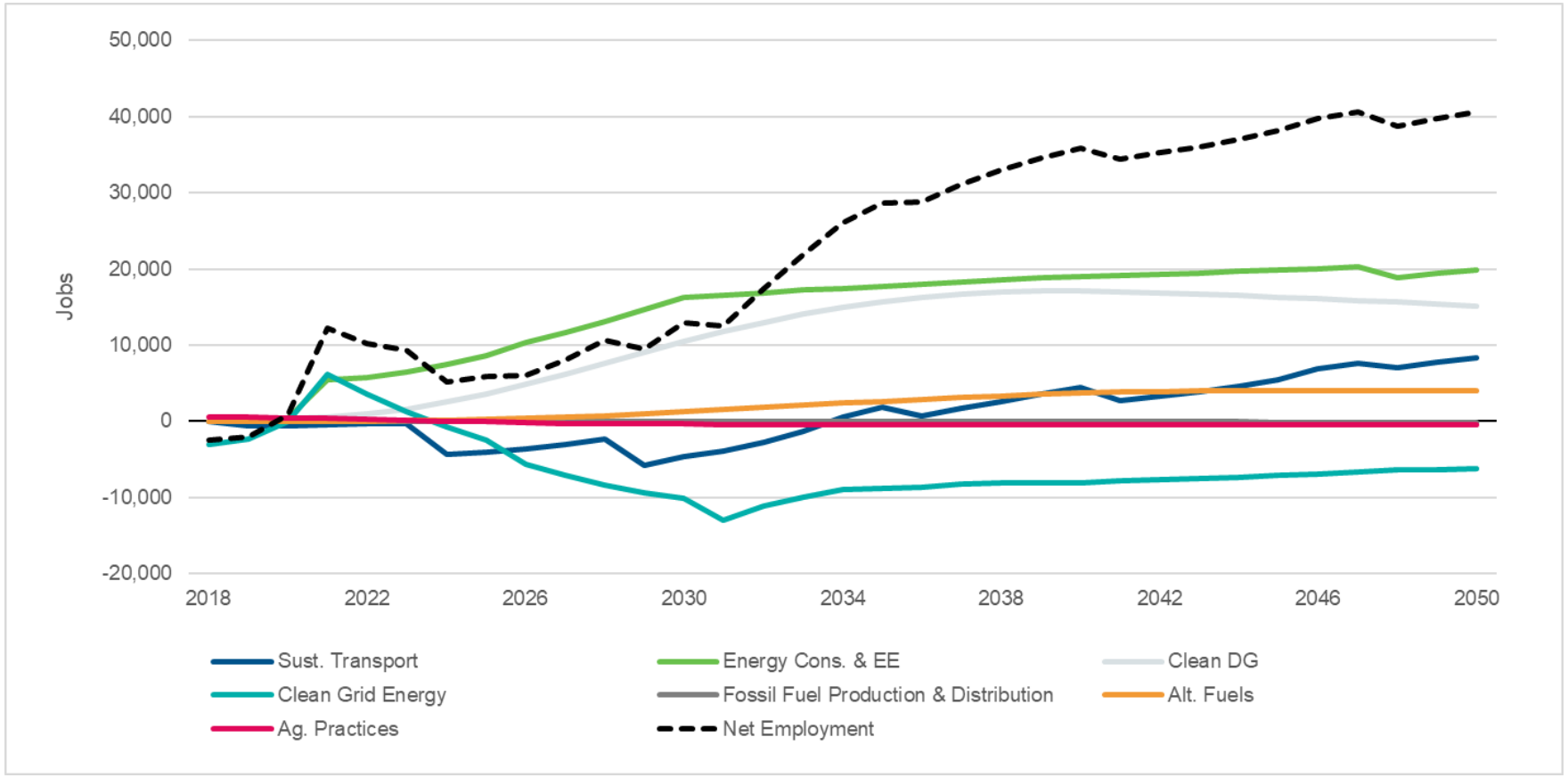
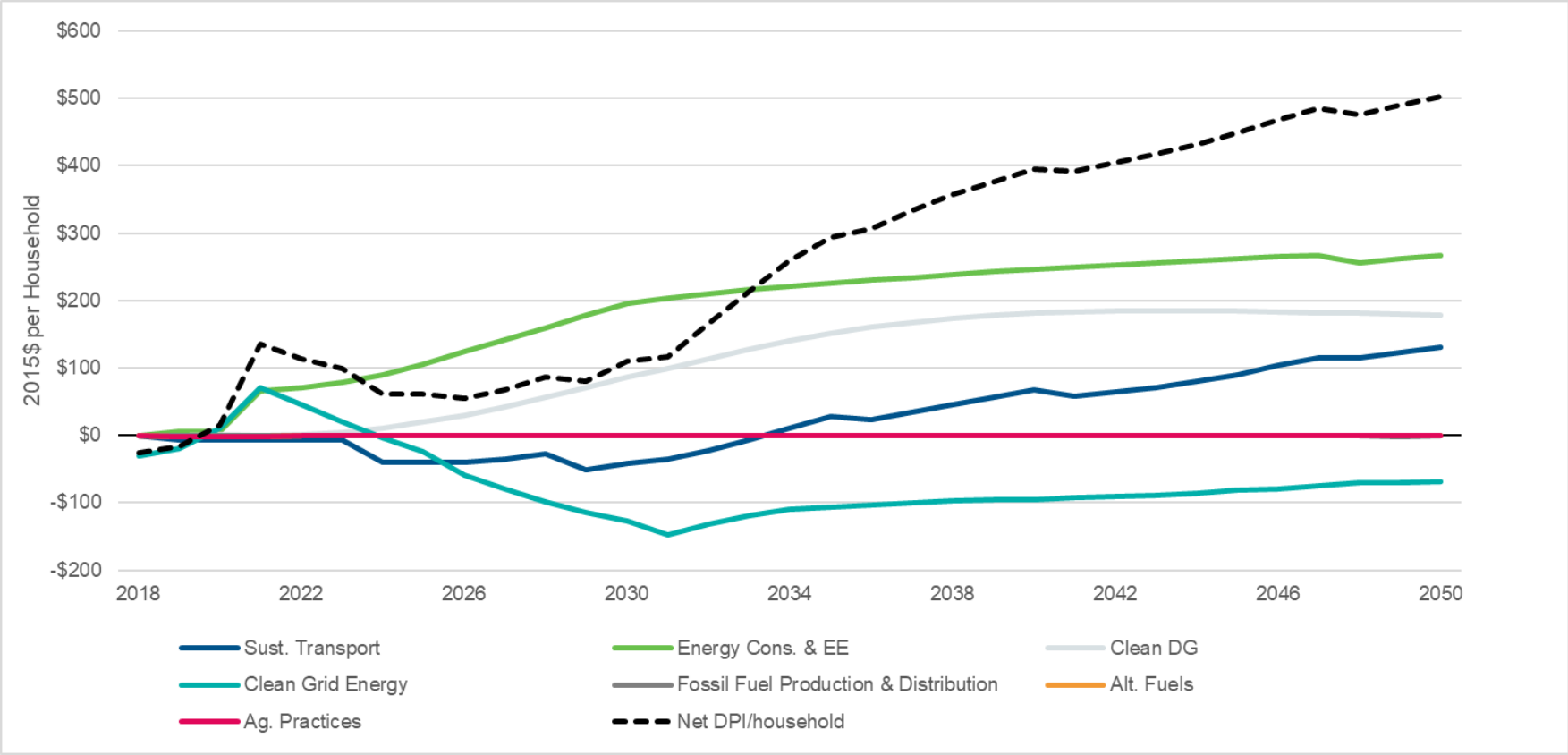
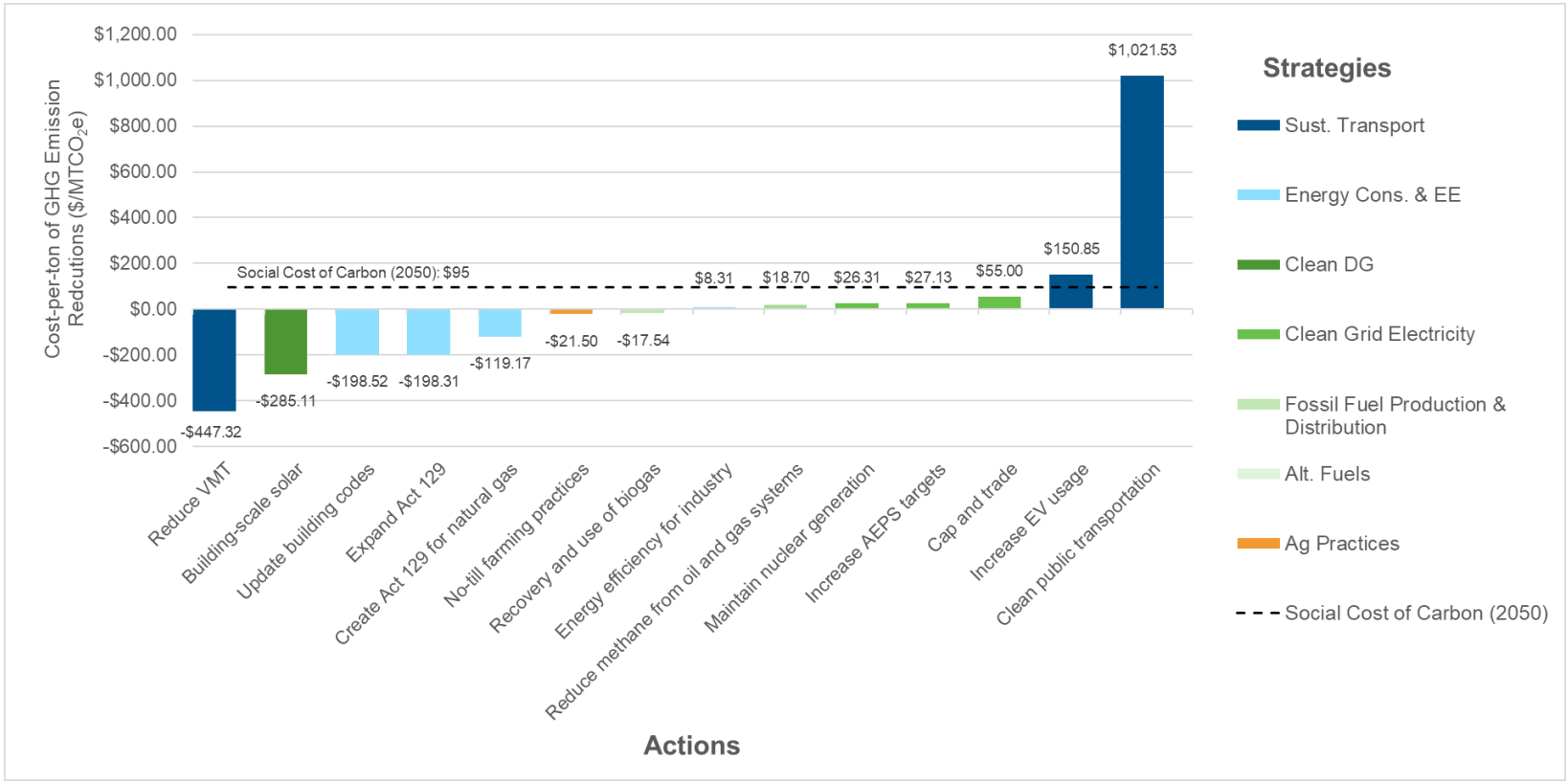


Figure 18. Change in Disposable Personal Income and in Disposable Income per Household Through 2050, by Strategy ($/Household)



Alt. Fuels and Fossil Fuel Production and Distribution Impacts are in line with the Ag. Practices strategy line in this chart.

Figure 19. Cost per Ton of CO_2 Reduced for All Actions, By Sector ($/MTCO$_2$e)



1. Blue shading indications emission reductions from strategies within the Energy Consumption sector; green shading indicates emission reductions from strategies within the Energy Production sector; and orange shading indicates emission reductions from strategies within the Agriculture sector.
2. Although combined heat and power (CHP) reduces GHG emissions through most of the assessment period, it is projected to result in a net increase in GHG emissions by 2050 when using an average emission factor to calculate GHG reductions, and therefore is not included in this chart. GHG emissions reduced through electricity savings are counter balanced by GHG emissions resulting from increased natural gas use. Note: the team looked primarily at the impacts from new natural gas combustion in new CHP systems and did not quantify the potential from using CHP to capture waste heat from existing combustion systems.
3. The Social Cost of Carbon (SCC) included in this chart is the 2050 SCC assuming a 2.5% discount rate (EPA 2016). The EPA presents a range of SCC for 2050 between $26-$212, adding that the IPCC states the SCC estimates omit various impacts that would likely increase damages. The models used to develop SCC estimates do not currently include all of the impacts of climate change. Therefore, the $95 amount was selected for this analysis as a reasonable and accurate assumption.

Table 10. Annual (2025 and 2050) and Cumulative (2018-2050) Change in Disposable Personal Income ($ Million) and Change in Disposable Personal Income Per Household[1] ($/Household)

Strategies Included in Quantitative Modeling	Annual Change in Disposable Personal Income ($ Million) (2025)	Annual Change in Disposable Personal Income ($ Million) (2050)	Cumulative Change in Disposable Personal Income ($ Million) (2018-2050)	Annual Change in Disposable Personal Income Per Household ($/Household) (2025)	Annual Change in Disposable Personal Income Per Household ($/Household) (2050)	Cumulative Change in Disposable Personal Income Per Household ($/Household) (2018-2050)
Increase end use energy conservation and efficiency	$492 (0.07%)	$1,246 (0.11%)	$28,446 (0.13%)	$105 (0.08%)	$267 (0.18%)	$6,089 (0.13%)
Implement sustainable transportation planning and practices	-$190 (-0.03%)	$611 (0.05%)	$3,951 (0.02%)	-$41 (-0.03%)	$131 (0.09%)	$846 (0.02%)
Increase use of clean, distributed electricity generation resources	$92 (0.01%)	$832 (0.07%)	$17,001 (0.08%)	$20 (0.01%)	$178 (0.12%)	$3,639 (0.08%)
Create a diverse portfolio of clean, utility-scale electricity generation	-$113 (-0.02%)	-$317 (-0.03%)	-$10,833 (-0.05%)	-$24 (-0.02%)	-$68 (-0.05%)	-$2,319 (-0.05%)
Reduce impacts of fossil fuel energy production and distribution	$0 (0.00%)	-$2 (0.00%)	-$27 (0.00%)	$0 (0.00%)	$0 (0.00%)	-$6 (0.00%)
Increase production and use of alternative fuels	$0 (0.00%)	$0 (0.00%)	$3 (0.00%)	$0 (0.00%)	$0 (0.00%)	$1 (0.00%)
Use agricultural best practices	$1 (0.00%)	-$23 (0.00%)	-$335 (0.00%)	$0 (0.00%)	-$5 (0.00%)	-$72 (0.00%)
Net Total[2]	**$283 (0.05%)**	**$2,348 (0.20%)**	**$38,206 (0.18%)**	**$61 (0.5%)**	**$503 (0.35%)**	**$8,180 (0.18%)**

[1] Results for disposable personal income and disposable personal income per household are discounted at 1.75%. Household data is taken from the U.S. Census Bureau.

[2] Each of the strategies were designed, included in the quantitative modeling, and analyzed independently in REMI. The net totals do not include interaction macroeconomic effects that would likely result from strategies implemented concurrently.

In aggregate, the suite of strategies recommended in this Plan maximize GHG reductions and are cost-effective for Pennsylvania. However, DEP, its sister agencies, and the Pennsylvania state legislature and executive branch will need to prioritize and phase strategy implementation for both the quantified and non-quantified strategies in this Plan. The year 2025 is rapidly approaching, and actions with large GHG and economic benefits, and relatively low cost and political barriers offer Pennsylvania the best short-term solutions. In parallel, initiating actions that may take more time and resources to implement and have more trade-offs to consider will help Pennsylvania maximize the potential impact of this Plan. Examples of these considerations are presented below.

Energy conservation and efficiency actions appear to be likely candidates for immediate implementation. These actions offer relatively large GHG reductions over time, provide cost savings (negative cost-per-ton of GHG reduced), and support growth in jobs. Many of the energy conservation and efficiency actions outlined in this Plan build upon existing Pennsylvania policies and programs that have widespread support, and therefore offer a low barrier for implementation. Further, many of these actions have important resilience benefits.

The case for sustainable transportation practices gets more compelling as time goes on. Most of the GHG benefits of this strategy come after 2025, positive job results are not seen until 2030, and the costs of reductions for actions under this strategy are relatively high compared to other actions. Nonetheless, state and local governments need to act now to realize the eventual benefits of this strategy and ensure infrastructure and policies are in place to drive and support market transformation. This will take time as the strategy will require public and private investment, scaling of infrastructure (e.g., bike shares and electric vehicle charging), and changes to consumer behavior to achieve the projected large climate and economic benefits through 2050.

Creating a diverse portfolio of clean, utility-scale electricity generation presents the most important trade-offs to consider. This strategy has an impact on almost every sector of the Pennsylvania economy, as well as residents, businesses, and government. The creation of clean utility-scale generation results in some possible negative net macroeconomic impacts, due to the multiple effects on Pennsylvania's generation mix and related energy industries. However, this strategy drives the largest reductions in GHG emissions of all the modeled strategies. Additionally, it has positive resilience impacts and appears to be cost-effective when considering the cost-per-ton of GHG reduced as compared to the social cost of carbon (see Figure 19).

Energy conservation and efficiency, sustainable transportation, and clean electricity generation are some of the most beneficial and impactful strategies that the commonwealth could pursue. However, as noted, the strategies quantified in this Plan provide only a starting point for significant GHG emission reductions. The 15 quantified actions are not enough to prevent catastrophic and irreversible climate change.

The impacts of climate change are real and will continue to put Pennsylvanians at risk from increased flooding, higher temperatures, and more. If not properly accounted for, these trends will threaten Pennsylvania in other ways: agriculture will have to adapt to greater extremes in temperature and precipitation; forests will be subject to multiple stressors; suitable habitat for plant and wildlife species is expected to shift to higher latitudes and elevations; winter recreation will decline; and public health

will deteriorate because climate change will worsen air quality relative to what it would otherwise be, causing increased respiratory and cardiac illness.

These impacts can be alleviated if the actions in this Plan are adopted, but leaders cannot be the only ones who act. All Pennsylvanians–including citizens, businesses, and leaders–need to consider each action presented in this Plan as part of their responsibility to combat and adapt to climate change. The benefits of acting include economic growth, jobs, cleaner air, resilience and more. If Pennsylvanians want to provide a prosperous commonwealth with clean air, water, and land for generations to come, now is the time to take action on climate change.

5 References

Abdalla, Charles, and Kristen Saacke Blunk. 2007. *Access and Allocation of Water in Pennsylvania*. Penn State Extension. https://extension.psu.edu/access-and-allocation-of-water-in-pennsylvania

Agriculture and Agri-Food Canada. 2000. Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project. http://www5.agr.gc.ca/resources/prod/doc/policy/environment/pdfs/aei/summary.pdf

Alliance to Save Energy (ASE). 2012. "Energy Efficiency: A Tool for Climate Change Adaptation." http://www.ase.org/sites/ase.org/files/ASE-EE_A_Tool_For_Climate_Change_Adaptation.pdf

America's Pledge. 2018a. *America's Low-Carbon Future: A Bottom-Up Opportunity Agenda for Climate Action in the United States.* https://www.bbhub.io/dotorg/sites/28/2018/07/Bloomberg_AmericasPledge_OpportunityAgendaReport_Final.pdf

America's Pledge. 2018b. *Fulfilling America's Pledge: How States, Cities, and Business are Leading the United States to a Low-Carbon Future.* https://www.americaspledgeonclimate.com/fulfilling-americas-pledge/

American Council for an Energy Efficient Economy (ACEEE). 2017. *State Energy Efficiency Resource Standards*. http://aceee.org/policy-brief/state-energy-efficiency-resource-standard-activity

American Council for an Energy-Efficient Economy (ACEEE). 2016. *Tracking Energy Efficiency Performance in the United States*. Accessed June 19, 2018. https://aceee.org/ee-metrics

Anderson, James L., Christopher M. Anderson, Jingjie Chu, and Jennifer Meredith. 2016. "Fishery Performance Indicators." Technical Report. doi:DOI: 10.13140/RG.2.2.32536.39681

Buchanan Ingersoll & Rooney. 2012. Pennsylvania Overhauls Oil and Gas Act. https://www.bipc.com/pennsylvania-overhauls-oil-and-gas-act

CALSTART. 2015. Electric Truck & Bus Grid Integration: Opportunities, Challenges & Recommendations. http://www.calstart.org/Libraries/Publications/Electric_Truck_Bus_Grid_Integration_Opportunities_Challenges_Recommendations.sflb.ashx

Cameron, Lorraine, Bethany Waterbury, and Martha Stanbury. 2013. *Indicators of the Potential Effects of Climate Change on Public Health: Michigan Resuluts, 2011.* Lansing: Michigan Climate & Health Adaptation Program (MICHAP). https://www.michigan.gov/documents/mdch/MI_Climate_Change_Indicators_2013_443695_7.pdf

Canadian Water and Wastewater Association (CWWA). 2009. *Water Conservation and Efficiency Performance Measures and Benchmarks within the Municipal Sector.* http://www.allianceforwaterefficiency.org/CWWA-Performance-Indicators.aspx

Center for Disease Control and Prevention (CDC). 2016. *Climate Change and Extreme Heat: What You Can Do to Prepare*. https://www.cdc.gov/climateandhealth/pubs/extreme-heat-guidebook.pdf

Center for Disease Control and Prevention (CDC). 2017a. Zika Virus: Prevent Mosquito Bites. https://www.cdc.gov/zika/prevention/prevent-mosquito-bites.html

Center for Disease Control and Prevention (CDC). 2017b. Zika Virus: Mosquito Control. *Information on Aerial Spraying*. https://www.cdc.gov/zika/vector/aerial-spraying.html

Center for Disease Control and Prevention (CDC). 2017c. Ticks: Preventing Tick Bites. https://www.cdc.gov/ticks/avoid/on_people.html

City of Philadelphia Mayor's Office of Sustainability. 2017. *Growing Stronger: Toward a Climate-Ready Philadelphia*. https://beta.phila.gov/media/20160504162056/Growing-Stronger-Toward-a-Climate-Ready-Philadelphia.pdf

City of Pittsburgh, Department of City Planning. 2017. *Pittsburgh's Resilience Strategy.* http://www.100resilientcities.org/wp-content/uploads/2017/07/Pittsburgh_-_Resilience_Strategy.pdf

Connecticut River Watershed Council, Inc. 2000. Providing fish passage around dams in the Northeast: a fishway for your stream. The Connecticut River Watershed Council, Inc., Easthampton, Massachusetts.

Conservation & Society. 2017. "List of Suggested Indicators." http://www.conservationandsociety.org/viewimage.asp?img=ConservatSoc_2017_15_2_217_208305_t1.jpg

Dumanski, Julian, Eugene Terry, Derek Byerlee, and Christian Pieri. 1998. *Performance Indicators for Sustainable Agriculture.* Discussion Note, Washington, D.C.: World Bank. http://siteresources.worldbank.org/INTARD/864477-1112703179105/20434502/SustInd.pdf

E2. 2018. *Clean Jobs Pennsylvania.* https://www.e2.org/wp-content/uploads/2018/06/Clean-Jobs-Pennsylvania-2018.pdf

Econsult Solutions. 2013. *The Economic Impacts of the Municipal Waste Industry in Pennsylvania*. http://pawasteindustries.org/site/wp-content/uploads/2017/03/PWIA-Economic-Impact-Study-FINAL-REPORT-2013-12-20.pdf

Energy and Biodiversity Initiative (EBI). 2009. *Biodiversity Indicators for Monitoring Impacts and Conservation Actions.* http://www.theebi.org/pdfs/indicators.pdf

Energy Information Administration (EIA). 2013. *Energy Use in Homes*. 5 Feb. 2013, https://www.eia.gov/energyexplained/index.php?page=us_energy_homes

Energy Information Administration (EIA). 2017a. *Electric Power Monthly*. Feb. 2017, https://www.eia.gov/electricity/monthly/ Tables 1.3.B, 1.10.B, 1.11.B

Energy Information Administration (EIA). 2017b. *Pennsylvania Profile Analysis*. 20 July 2017, https://www.eia.gov/state/analysis.php?sid=PA

Energy Information Administration (EIA). 2017c. *Energy Use in Commercial Buildings*. 17 Aug. 2017, www.eia.gov/energyexplained/index.php?page=us_energy_commercial.

Energy Information Administration (EIA). 2018. *Energy Use for Transportation*. 23 May 2018, https://www.eia.gov/energyexplained/?page=us_energy_transportation

Farmer-to-Farmer. 2015. *Farmer-to-Farmer Program Standard Performance and Impact Indicators.* Washington, D.C.: http://farmer-to-farmer.org/resources/farmer-farmer-program-standard-performance-and-impact-indicators

Federal Emergency Management Agency (FEMA). 2016. Pennsylvania Severe Storms and Flooding (DR-4292). https://www.fema.gov/disaster/4292

Federal Emergency Management Agency (FEMA). 2017. America's Preparathon: Take Action. https://community.fema.gov/take-action/activities?lang=en_US

Federal Highway Administration (FHWA). 2018. FHWA Forecasts of Vehicle Miles Traveled (VMT): Spring 2018. https://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_forecast_sum.pdf

Georgia Institute of Technology (GIT). 2009. Meta-Review of Efficiency Potential Studies and Their Implications for the South. https://smartech.gatech.edu/handle/1853/30189

Governor Tom Wolf. 2018. *Governor Wolf Signs New Legislation to Support Low-Cost, Clean Energy Technology in Pennsylvania*. https://www.governor.pa.gov/governor-wolf-signs-new-legislation-support-low-cost-clean-energy-technology-pennsylvania/

Held, Anne, Mario Ragwitz, Erik Merkel, Max Rathmann, and Corinna Klessmann. 2010. *Indicators Assessing the Performance of Renewable Energy Support Policies in 27 Member States.* Karlsruhe: Re-Shaping: Shaping an Effective and Efficient European Renewable Energy Market. http://www.reshaping-res-policy.eu/downloads/RE-Shaping%20D5D6_Report_final.pdf

Horton, R., G. Yohe, W. Easterling, R. Kates, M. Ruth, E. Sussman, A. Whelchel, D. Wolfe, and F. Lipschultz. 2014. Chapter 16: Northeast. Climate Change Impacts in the United States: The Third National Climate Assessment, J.M. Melillo, Terese Richmond, and G.W. Yohe, Eds., U.S. Global Change Research Program, 16-1-nn. https://nca2014.globalchange.gov/report/regions/northeast

ICF. Combined Heat and Power Database. Proprietary.

Intergovernmental Panel on Climate Change (IPCC). 2014. *Climate Change 2014 Synthesis Report Summary for Policymakers.* http://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf

International Energy Agency (IEA). 2008. *Assessing Measures of Energy Efficiency Performance and Their Application in Industry.* Paris: Organisation for Economic Cooperation and Development (OECD). https://www.iea.org/publications/freepublications/publication/JPRG_Info_Paper.pdf

International Energy Agency (IEA). 2015. "Building Energy Performance Metrics: Supporting Energy Efficiency Progress in Major Economies." http://www.buildingrating.org/sites/default/files/1448011796IEA_IPEEC_BEET4_Final_Report.pdf

Keystone Energy Efficiency Alliance (KEEA). 2016. *Act 129*. https://keealliance.org/act-129/

Luber, G., et. al. 2014. Ch. 9: Human Health. *Climate Change Impacts in the United States: The Third National Climate Assessment*. J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds. U.S. Global Change Research Program. 220-256. doi:10.7930/J0PN93H5.

Maryland Department of the Environment (MDE). 2013. Resiliency and Water Resources Management: Water Supply in a Changing Climate. http://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Publications/IAN4182.pdf

McNeil, Michael, Stephane de la Rue du Can, Dan Hamza-Goodacre, and Prodipto Roy. 2016. *Energy Efficiency Indicators and Impact Metrics.* U.S. Department of Energy. https://eta.lbl.gov/sites/all/files/publications/lbnl-1005695_energy_efficiency_indicators.pdf

McRae, T., C.A.S. Smith, and L.J. Gregorich (eds). 2000. *Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project. A Summary.* Agriculture and Agri-Food Canada, Ottawa, Ont. http://www5.agr.gc.ca/resources/prod/doc/policy/environment/pdfs/aei/summary.pdf

Montreal Process. 1995. *Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests.* Santiago: Working Group on Criteria and Indicators for Conservation and Sustainable Management of Temperate and Boreal Forests. https://www.montrealprocess.org/documents/publications/techreports/1995santiago_e.pdf

Nassif, Hani, Kaan Ozbay, Devajyoti Deka, Peng Lou, Chaekuk Na, Sandeep Mudigonda, Yuan Zhu, Ender Faruk Morgul, Bekir Bartin, and Ayman El-Awar. 2017. *Performance Measures to Assess Resiliency and Efficiency of Transit Systems.* San Jose: Mineta Transportation Institute Publications. http://scholarworks.sjsu.edu/cgi/viewcontent.cgi?article=1225&context=mti_publications

National Caucus of Environmental Legislators (NCEL). 2015. Tourism and Outdoor Recreation. http://ncel.net/wp-content/uploads/2015/12/Tourism-and-Outdoor-Recreation-White-Paper.pdf

National Institute of Building Sciences. 2017. *Natural Hazard Mitigation Saves: 2017 Interim Report.* https://www.nibs.org/page/ms2_dwnload

Natural Resources Defense Council (NRDC). 2013. *Getting Climate Smart Strategy Toolbox*. https://www.nrdc.org/sites/default/files/getting-climate-smart-strategy-toolbox.pdf

NC Clean Energy Technology Center. 2017. *Alternative Energy Portfolio Standard*. DSIRE. 24 Jan. 2017, www.dsireusa.org.

New Hampshire Department of Environmental Services (NH DES). 2015. *Emergency Response Planning Guide*. https://www.des.nh.gov/organization/divisions/water/wweb/documents/emergency-response-guide.pdf

New York Department of Environmental Protection (NYC DEP). 2016. *Green Infrastructure Performance Metrics Report.* The City of New York Department of Environmental Protection. http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi-performance-metrics-report-2016.pdf

NYC Mayor's Office of Recovery and Resiliency. 2018. *Climate Resiliency Design Guidelines*. http://www1.nyc.gov/assets/orr/pdf/NYC_Climate_Resiliency_Design_Guidelines_v2-0.pdf

Organisation for Economic Cooperation and Development (OECD). 2014. "Climate Change, Water and Agriculture: Towards Resilient Systems". http://dx.doi.org/10.1787/9789264209138-en

Outdoor Industry Association. 2017. *Pennsylvania Outdoor Recreation Economy Report*. https://outdoorindustry.org/resource/pennsylvania-outdoor-recreation-economy-report/

Pakzad, Parisa, Paul Osmond, and Linda Corkery. 2017. "Developing Key Sustainability Indicators for Assessing Green Infrastructure Performance." *Procedia Engineering* 180: 146-156. doi:doi:10.1016/j.proeng.2017.04.174

Penn State Agriculture and Environment Center. 1 Mar. 2017. *Pennsylvania in the Balance*. https://agsci.psu.edu/aec/research-extension/conferences-and-workshops/pa-in-balance/default/extension_publication_file

Pennsylvania Department of Agriculture (PDA). 2018. *Pennsylvania Agriculture: A Look at the Economic Impact and Future Trends.* http://www.agriculture.pa.gov/Documents/PennsylvaniaAgriculture_EconomicImpactFutureTrends.pdf

Pennsylvania Department of Community & Economic Development (PA DCED). *Natural Gas*. https://dced.pa.gov/key-industries/naturalgas/Accessed October 25, 2018.

Pennsylvania Department of Conservation and Natural Resources (DCNR). 2015. *DCNR and Climate Change: Planning for the Future*. http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20031815.pdf

Pennsylvania Department of Conservation and Natural Resources (DCNR). 2018. *Climate Change Adaptation and Mitigation Plan*. http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20033655.pdf

Pennsylvania Department of Conservation and Natural Resources (PA DCNR). 2018. *Climate Change Website.* http://www.dcnr.pa.gov/Conservation/ClimateChange/Pages/default.aspx

Pennsylvania Department of Conservation and Natural Resources (PA DCNR). 2017. Economic Impact of Local Parks, Recreation and Open Space in Pennsylvania. http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_009692.pdf

Pennsylvania Department of Environmental Protection (PA DEP). 2014. *Pennsylvania Climate Adaptation Planning Report: Risks and Practical Recommendations.* http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-103584/2700-RE-DEP4303%20Combined.pdf

Pennsylvania Department of Environmental Protection (PA DEP). 2015. *Climate Change Action Plan Update*.

Pennsylvania Department of Environmental Protection (PA DEP). 2018a. *Drive Electric Pennsylvania Coalition.* http://www.dep.pa.gov/Business/Energy/OfficeofPollutionPrevention/State-Energy-Plan/Pages/Drive-Electric-PA-Coalition.aspx

Pennsylvania Department of Environmental Protection (PA DEP). 2018b. *Finding Pennsylvania's Solar Future.* http://www.dep.pa.gov/Business/Energy/OfficeofPollutionPrevention/SolarFuture/Pages/Finding-Pennsylvania%E2%80%99s-Solar-Future.aspx

Pennsylvania Department of Environmental Protection (PA DEP). 2018c. *Alternative Fuels Incentive Grant Program (AFIG).* http://www.dep.pa.gov/citizens/grantsloansrebates/alternative-fuels-incentive-grant/pages/default.aspx

Pennsylvania Department of Environmental Protection (PA DEP). 2018d. General Plan Approval and/or General Operating Permit, BAQ-GPA/GP-5, Natural Gas Compression Stations, Processing Plants, and Transmission Stations. http://www.depgreenport.state.pa.us/elibrary/GetDocument?docId=19614&DocName=01%20GP-5%20NATURAL%20GAS%20COMPRESSION%20STATIONS%2c%20PROCESSING%20PLANTS%20AND%20TRANSMISSION%20STATIONS%20GENERAL%20PLAN%20APPROVAL%20AND/OR%20GENERAL%20OPERATING%20PERMIT.PDF%20%20%3Cspan%20style%3D%22color:blue%3b%22%3E%28NEW%29%3C/span%3E

Pennsylvania Department of Environmental Protection (PA DEP). 2018e. General Plan Approval and/or General Operating Permit, BAQ-GPA/GP-5A, Unconventional Natural Gas Well Site Operations and Remote Pigging Stations. http://www.depgreenport.state.pa.us/elibrary/GetDocument?docId=19615&DocName=02%20GP-5A%20UNCONVENTIONAL%20NATURAL%20GAS%20WELL%20SITE%20OPERATIONS%20AND%20REMOTE%20PIGGING%20STATIONS%20GENERAL%20PLAN%20APPROVAL%20AND/OR%20GENERAL%20OPERATING%20PERMIT.PDF%20%20%3Cspan%20style%3D%22color:blue%3b%22%3E%28NEW%29%3C/span%3E

Pennsylvania Department of Environmental Protection (PA DEP). *Coastal Resources Management Program.* www.dep.pa.gov/Business/Water/Compacts%20and%20Commissions/Coastal%20Resources%20Management%20Program/Pages/About-the-Program.aspx.

Pennsylvania Department of Transportation (PennDOT). 2017. *PennDOT Extreme Weather Vulnerability Study, Phase 1*. http://s3.amazonaws.com/tmp-map/climate/doc/StudyReport-PaVulnerabilityStudy-ver040317.pdf

Pennsylvania Forest Products Association. 2003. *Penn's Woods: The Forest Resource and Forest Products Industry of Pennsylvania.* http://paforestproducts.org/downloads/pennswoods.pdf

Pennsylvania General Assembly (PA General Assembly). 2008. *Pennsylvania Climate Change Act – Enactment Act of Jul. 9, 2008, P.L. 935, No. 70.* http://www.legis.state.pa.us/cfdocs/Legis/LI/uconsCheck.cfm?txtType=HTM&yr=2008&sessInd=0&smthLwInd=0&act=70

Pennsylvania General Assembly (PA General Assembly). 2012. House Bill 1950 – Oil and Gas (58 PA.C.S.) – Omnibus Amendments Act of February 14, 2012, P.L. 87, No. 13. http://www.legis.state.pa.us/CFDOCS/LEGIS/LI/uconsCheck.cfm?txtType=HTM&yr=2012&sessInd=0&smthLwInd=0&act=0013.&CFID=126352892&CFTOKEN=56814378

Pennsylvania General Assembly (PA General Assembly). 2017. House Bill 118 – Administrative Code of 1929 – Omnibus Amendments Act of Oct. 30, 2017, P.L. 379, No 40. http://www.legis.state.pa.us/cfdocs/legis/li/uconsCheck.cfm?yr=2017&sessInd=0&act=40

Pennsylvania Public Utilities Commission (PA PUC). *Act 129 Information Website.* http://www.puc.state.pa.us/filing_resources/issues_laws_regulations/act_129_information.aspx. Accessed October 25, 2018.

Pennsylvania Public Utility Commission (PA PUC). 2015. *Statewide Evaluation Team Energy Efficiency Potential Study for Pennsylvania*. http://www.puc.pa.gov/pcdocs/1345079.pdf

Pennsylvania Public Utility Commission (PA PUC). 2017. *Energy Efficiency & Conservation Information for Your Home.* http://www.puc.state.pa.us/General/consumer_ed/pdf/EEC_Home-FS.pdf

Pennsylvania Public Utility Commission (PA PUC). 2018. *Pennsylvania Alternative Energy Credit Program Website.* https://www.pennaeps.com/aboutaeps/

Pew Charitable Trusts (PEW). 2018. What We Don't Know About State Spending on Natural Disasters Could Cost Us. http://www.pewtrusts.org/-/media/assets/2018/06/statespendingnaturaldisasters_v4.pdf

Prabhu, Ravi, Carol Colfer, and Gill Shepherd. 1998. *Criteria and Indicators for Sustainable Forest Management: New Findings from CIFOR's Forest Management Unit Level Research.* Rural Development Forestry Network. https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/1178.pdf

Prior, Tim. 2015. *Measuring Critical Infrastructure Resilience: Possible Indicators.* Risk and Resilience Report 9, Zurich: Center for Security Studies. http://www.academia.edu/12461253/Measuring_Critical_Infrastructure_Resilience_Possible_indicators

Reytar, Katie, Craig Hanson, and Norbert Henninger. 2014. *Indicators of Sustainable Agriculture: A Scoping Analysis.* Working Paper, World Resources Institute. https://www.wri.org/sites/default/files/wrr_installment_6_sustainable_agruiculture_indicators.pdf

Shortle, James, David Abler, Seth Blumsack, Aliana Britson, Kuai Fang, Armen Kemanian, Paul Knight, Marc McDill, Raymond Najjar, Michael Nassry, Richard Ready, Andrew Ross, Matthew Rydzik, Chaopeng Shen, Shilong Wang, Denice Wardrop, Susan Yetter. 2015. *Pennsylvania Climate Impacts Assessment Update.* Pennsylvania State University. https://www.pennfuture.org/Files/Admin/Pennsylvania-Climate-Impacts-Assessment-Update---2700-BK-DEP4494.compressed.pdf

Smart Commute. 2015. "Annual Review." http://smartcommute.ca/wp-content/uploads/2014/07/SC_Annual-Review-Final-EN.pdf

Solar United Neighbors. 2017. Keystone State looks to grow local solar by closing SREC market. https://www.solarunitedneighbors.org/keystone-state-looks-grow-local-solar-closing-srec-market/

Sothern, Marci. 26 Sept. 2017. *Four Ecosystems of Pennsylvania.* https://sciencing.com/four-ecosystems-of-pennsylvania-13662842.html

Spector, Herschel. 2018. *Destroying New York State's Climate Change Efforts, Revision 1.*

Straub, Craig, and Brian Kwiatkowski. 2014. *The Metrics of BMPs.* Storm Water Solutions. https://www.estormwater.com/sites/estormwater.com/files/BMPs%20Apex%20Co.%20LLC.pdf

Swistock, Bryan R, et al. 2009. *Drinking Water Quality in Rural Pennsylvania and the Effect of Management Practices*. Pennsylvania State University.

Tourism Economics. 2015. *Competitive Analysis of Pennsylvania's Tourism Budget*.

U.S. Climate Resilience Toolkit. 2018. *Glossary*. https://toolkit.climate.gov/content/glossary

U.S. Department of Agriculture (USDA). 2012. *Pennsylvania State Profile*. *Census of Agriculture*

U.S. Department of Agriculture (USDA). 2013. Greenhouse Gas Mitigation Options and Costs for Agricultural Land and Animal Production within the United States. https://www.usda.gov/oce/climate_change/mitigation_technologies/GHG_Mitigation_Options.pdf

U.S. Department of Agriculture (USDA). 2014. https://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Annual_Statistical_Bulletin/2013_2014/

U.S. Department of Agriculture (USDA). 2018. *Nearby Nature – A Cost-Effective Prescription for Better Community Health?* PNW Science Findings. Issue 203.

U.S. Department of Commerce (DOC). 2018. Bureau of Economic Analysis Interactive Data Application: GDP and Personal Income, Pennsylvania. https://www.bea.gov/iTable/iTable.cfm?reqid=70&step=10&isuri=1&7003=200&7035=-1&7004=sic&7005=1&7006=xx&7036=-1&7001=1200&7002=1&7090=70&7007=-1&7093=levels#reqid=70&step=10&isuri=1&7003=200&7004=naics&7035=-1&7005=-1&7006=42000&7001=1200&7036=-1&7002=1&7090=70&7007=2017&7093=levels

U.S. Department of Energy (DOE). 2015. Preparing for a Power Outage. https://energy.gov/articles/preparing-power-outage

U.S. Department of Energy (DOE). 2018. *Performance Metrics Tiers.* Accessed July 7, 2018. https://www.energy.gov/eere/buildings/performance-metrics-tiers

U.S. Department of Homeland Security (DHS). 2017. Build a Kit: Water. https://www.ready.gov/water

U.S. Department of Labor, Occupational Safety and Health Administration (OSHA). 2017. About Work/Rest Schedules. https://www.osha.gov/SLTC/heatillness/heat_index/work_rest_schedules.html

U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. 2013. *2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Pennsylvania.* https://digitalmedia.fws.gov/cdm/singleitem/collection/document/id/1697/rec/1

U.S. Energy Information Administration (EIA). 2018. Annual Energy Outlook. Accessed July 3, 2018. Available at: https://www.eia.gov/outlooks/aeo/

U.S. Environmental Protection Agency (EPA). 2002. Cases in Water Conservation: How Efficiency Programs Help Water Utilities Save Water and Avoid Costs. https://www.epa.gov/sites/production/files/2017-03/documents/ws-cases-in-water-conservation.pdf

U.S. Environmental Protection Agency (EPA). 2011. *Guide to Sustainable Transportation Performance Measures.* https://www.epa.gov/sites/production/files/2014-01/documents/sustainable_transpo_performance.pdf

U.S. Environmental Protection Agency (EPA). 2014*. The Economic Benefits of Green Infrastructure: A Case Study of Lancaster, PA*. https://www.epa.gov/sites/production/files/2015-10/documents/cnt-lancaster-report-508_1.pdf

U.S. Environmental Protection Agency (EPA). 2016b. *Heat Islands: Heat Island Cooling Strategies*. https://www.epa.gov/heat-islands/heat-island-cooling-strategies

U.S. Environmental Protection Agency (EPA). 2016c. *Reducing Methane Emissions from the Oil and Natural Gas Industry.* https://www.epa.gov/sites/production/files/2016-09/documents/20160310fs1.pdf

U.S. Environmental Protection Agency (EPA). 2016d. *Recycling Economic Information (REI) Report.* https://www.epa.gov/smm/recycling-economic-information-rei-report#findings

U.S. Environmental Protection Agency (EPA). 2017a. Green Vehicle Guide: Consider a SmartWay Vehicle. https://www.epa.gov/greenvehicles/consider-smartway-vehicle

U.S. Environmental Protection Agency (EPA). 2017b. Green Vehicle Guide: Discover Fuel-Saving Tips. https://www.epa.gov/greenvehicles/discover-fuel-saving-tips

U.S. Environmental Protection Agency (EPA). 2017c. Smart Growth and Climate Change. https://www.epa.gov/smartgrowth/smart-growth-and-climate-change

U.S. Environmental Protection Agency (EPA). 2017d. WaterSense: Watering Tips. https://www.epa.gov/watersense/watering-tips

U.S. Environmental Protection Agency (EPA). 2017e. WaterSense: WaterSense for Kids. https://www.epa.gov/watersense/watersense-kids#tab-2

U.S. Environmental Protection Agency (EPA). 2017f. Waste Management Planning to Mitigate the Impacts of Climate Change. https://www.epa.gov/homeland-security-waste/waste-management-planning-mitigate-impact-climate-change. Accessed October 26, 2018.

U.S. Environmental Protection Agency (EPA). 2018a. "National Enforcement Initiative: Keeping Raw Sewage and Contaminated Stormwater Out of Our Nation's Waters". https://www.epa.gov/enforcement/national-enforcement-initiative-keeping-raw-sewage-and-contaminated-stormwater-out-our

U.S. Environmental Protection Agency (EPA). 2018b. WaterSense. https://www.epa.gov/watersense

U.S. Environmental Protection Agency (EPA.) 2016a. *Best Practices to Consider When Evaluating Water Conservation and Efficiency as an Alternative for Water Supply Expansion.* Washington, DC: https://www.epa.gov/sites/production/files/2016-12/documents/wc_best_practices_to_avoid_supply_expansion_2016_508.pdf

U.S. Global Change Research Program (USGCRP). 2017. "Highlights of the U.S. Global Change Research Program Climate Science Special Report". https://science2017.globalchange.gov/downloads/CSSR_Executive_Summary.pdf

U.S. National Aeronautics and Space Administration (NASA). 2018. *Responding to Climate Change Website.* https://climate.nasa.gov/solutions/adaptation-mitigation/

Uniform Construction Code Review and Advisory Council (UCC RAC). 2018. *Re: Re-review of the 2015 I-codes for adoption as the Uniform Construction Code.* May 1, 2018. https://www.dli.pa.gov/ucc/Documents/rac/UCC-RAC-2015-Code-Review-Report.pdf

United Nations Framework Convention on Climate Change (UNFCCC). 2015. *U.S.A. First Nationally Determined Contribution (NDC) Submission.* http://www4.unfccc.int/ndcregistry/PublishedDocuments/United%20States%20of%20America%20First/U.S.A.%20First%20NDC%20Submission.pdf

University of Maryland Center for Integrative Environmental Research. 2008. *Economic Impacts of Climate Change on Pennsylvania.* http://cier.umd.edu/climateadaptation/Pennsylvania%20Economic%20Impacts%20of%20Climate%20Change%20Full%20Report.pdf

USGCRP. 2018. *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Vol. II.* Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart eds. U.S. Global Change Research Program. Washington, DC, USA. 1515 pp. dio:10.7930/NCA4.2018

Water Environment Research Foundation (WERF). 2007. *Using Rainwater to Grow Livable Communities, Metrics and Measures.* http://www.werf.org/liveablecommunities/pdf/metrics.pdf

Watkiss, Paul, Alistair Hunt, and Matthew Savage. 2014. "Early VfM Adaptation Toolkit: Delivering value-for-money adaptation with iterative frameworks and low-regret options." *Evidence on Demand.* https://assets.publishing.service.gov.uk/media/57a089a9e5274a31e00001e4/Early_VfM_Toolkit.pdf

Whetstone, King. 14 Aug. 2014. *Many Facets of Pennsylvania Agriculture.* US Department of Agriculture. https://www.usda.gov/media/blog/2014/08/14/many-facets-pennsylvania-agriculture.

Wilgus, Carl. 25 Aug. 2014. *How to Continue Growth of Tourism Industry*. The Morning Call.

World Health Organization (WHO). 1 Feb. 2018. *Climate Change and Health.* https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health.

World Health Organization (WHO). 2007. *Benchmarks, Standards and Indicators for Emergency Preparedness and Response.* New Delhi: http://www.searo.who.int/entity/emergencies/topics/EHA_Benchmarks_Standards11_July_07.pdf

Yale University. 2018. *Environmental Performance Index (EPI) Report.* https://epi.envirocenter.yale.edu/2018-epi-report/agriculture

Appendix A. Technical Support for Strategy and Action Modeling

This appendix documents the assumptions, methods, data, and results for mitigation actions modeled for the 2018 Climate Action Plan (CAP) update. Macro-economic modeling and results are not covered in this appendix which is in line with and underlying many of the actions and implementation information provided in the actual Climate Action Plan.

The strategies and actions discussed in this appendix are one piece of the CAP that fit into a more comprehensive plan. There are 15 actions, as part of 7 strategies, that were quantitatively analyzed. There are dozens of other actions and strategies that are qualitatively addressed in the CAP which will lead to additional GHG reductions and benefits for Pennsylvanians.

Energy, micro-economic, and environmental inputs and results are presented below. Particularly for the energy-related actions, the descriptions of assumptions, methods, and data focus mainly on energy and economic modeling. Environmental and climate benefits and costs are calculated using emission factors from a range of sources, such as the Environmental Protection Agency's (EPA's) State Inventory Tool, EPA's Emissions & Generation Resource Integrated Database (eGRID), and 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The draft results presented in this document feed into macro-economic modeling being done in REMI.

Table 11. Annual GHG Reductions in 2025 and 2050, Cost per Ton of GHGs Reduced, and Net Present Value for All Strategies and Actions

Strategies and Actions Included in Higher-Level Strategy Quantitative Modeling	Annual GHG Reductions in 2025 ($MTCO_2e$)	Annual GHG Reductions in 2050 ($MTCO_2e$)	Cost per Ton of GHG Reduced ($/$MTCO_2e$)	Net Present Value ($ Million)
Increase end use energy conservation and efficiency	**5,827,879**	**12,036,172**	**-$127**	**$37,487**
Update building codes	1,164,587	5,374,682	-$199	$18,345
Increase adoption of energy efficiency, and expand Act 129	1,916,947	1,984,261	-$198	$14,916
Create an Act 129-like conservation and efficiency program for natural gas	845,010	1,567,198	-$119	$4,944
Expand energy assessments and provide more trainings on energy efficiency for industry	1,901,335	3,110,031	$8	-$718
Implement sustainable transportation planning and practices	**1,061,309**	**24,968,921**	**$71**	**-$20,397**
Reduce vehicle miles traveled for single-occupancy vehicles	573,260	2,820,936	-$447	$20,114

Strategies and Actions Included in Higher-Level Strategy Quantitative Modeling	Annual GHG Reductions in 2025 ($MTCO_2e$)	Annual GHG Reductions in 2050 ($MTCO_2e$)	Cost per Ton of GHG Reduced ($/MTCO_2e$)	Net Present Value ($ Million)
Implement a strategic plan and incentives for increasing electric vehicle use	474,100	21,689,937	$151	-$35,983
Increase the use of clean public transportation through electric municipal bus fleets	13,948	458,048	$1,022	-$4,527
Increase use of clean, distributed electricity generation resources	**544,502**	**-1,512,918**	**NA[ab]**	**$8,166**
Invest in and promote building-scale solar	NA[a]	48,210	-$285	$490
Incentivize and increase use of combined heat and power	544,502	-1,561,128	NA[b]	$7,295
Create a diverse portfolio of clean, utility-scale electricity generation	**30,015,060**	**48,792,751**	**$29**	**-$27,526**
Increase Alternative Energy Portfolio Standard(AEPS) Tier 1 targets, and further increase in-state generation and use of renewables	6,703,719	27,639,941	$27	-$13,551
Implement policy to maintain nuclear generation at current levels	18,412,115	21,152,811	$26	-$14,463
Limit carbon emissions through an electricity sector cap and trade program	4,899,227	NA[c]	$55	-$5,174
Reduce impacts of fossil fuel energy production and distribution	**104,879**	**29,598**	**$19**	**-$59**
Implement policies and practices to reduce methane emissions across oil and natural gas systems	104,879	29,598	$19	-$59
Increase production and use of alternative fuels	**1,673,531**	**2,796,683**	**-$20**	**$1,299**
Increase recovery and use of gas from coal mines, agriculture, wastewater, and landfills for energy	1,673,531	2,796,683	-$20	$1,299
Use agricultural best practices	**208,331**	**328,070**	**-$22**	**$162**
Increase and provide training for no-till farming practices	208,331	328,070	-$22	$162

[a] There is sufficient building scale solar in 2025 in the BAU to meet the 6% solar carve out assuming 90% is utility scale and 10% is building scale, so there are no GHG reductions from BAU in 2025. We see non-zero savings starting in 2026.

[b] Because this action (CHP) is projected to result in a net increase in GHG emissions by 2050 when using an average emission factor to calculate GHG reductions, a reduction cost per ton is not an applicable metric as it does not allow for a consistent comparison of costs per ton across the various strategies and actions. GHG emissions reduced through electricity savings are counter-balanced by GHG emissions resulting from increased natural gas use. However, when looking at emission reductions based on marginal emission factors, GHG reductions from CHP are positive across the entire time series through 2050, although they taper significantly at the end of the time series.

In this modeling analysis, that point occurs during the 2040s. Note: the team looked at the impacts from new natural gas combustion in new CHP systems and did not quantify the potential from using bottoming cycle CHP to capture waste heat from existing combustion systems, which was beyond the scope of this analysis.
[c]The GHG emission reductions from expanding AEPS requirements and maintaining nuclear generation are projected in this modeling analysis to meet the cap in 2050 without a cap and trade program.
Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU. Negative cost-per-ton represents net cost savings

Sector: Energy Consumption

Strategies include:

- Increase end use energy conservation and efficiency
- Implement sustainable transportation planning and practices

Strategy: Increase end use energy conservation and efficiency

Actions include:

- Update building codes
- Increase adoption of energy efficiency, and expand Act 129
- Create an Act 129-like conservation and efficiency program for natural gas
- Expand energy assessments and provide more trainings on energy efficiency for industry

Action: Update building codes

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- Residential
    - Energy Savings: Using ICF's Energy Code Calculator,[17] the analysis team assumes an International Energy Conservation Code (IECC) 2009 base code and then implements projected future IECC code versions every six years through 2050. This implementation timeframe is based on the actual time it took to adopt the 2015 codes in Pennsylvania.[18] The team assumes 90 percent code compliance for all new construction homes with a 30-year measure life. New home projections are provided by Pacific Northwest National Laboratory.[19] This approach delivers both electricity and natural gas savings.

[17] The Energy Codes calculator is a proprietary tool that estimates changes in energy use based on assumed updates to building codes for new construction.
[18] In May 2018 Pennsylvania moved ahead with adopting the 2015 model International Energy Conservation Code commercial and residential energy codes, while incorporating some select improvements from the 2018 model code. These changes will go into effect in October of 2018. https://www.dli.pa.gov/ucc/Documents/rac/UCC-RAC-2015-Code-Review-Report.pdf
[19] Pacific Northwest National Laboratory. (PNNL). 2014. Utility Savings Estimator. Accessed on July 13, 2018. Available at https://www.energycodes.gov/resource-center/utility-savings-estimators

- Costs: The team assumes an incremental cost of $2,561 per home for efficiency measures, which comes from PECO's Incremental Cost Database.[20]

- Commercial
  - Energy Savings: Again, using ICF's Code Calculator, the team assumes an American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 2007 base code and implement projected future ASHRAE code versions every 6 years through 2050. The team assumes 90 percent code compliance for all new construction, renovations, and additions with a 30-year measure life. New commercial square foot projections are provided by Pacific Northwest National Laboratory.[21] This approach delivers both electricity and natural gas savings.
  - Costs: The team assumes an incremental cost of $5.32 per sq. ft. for efficiency measures, which comes from Pacific Northwest National Laboratory's 2015 study *Cost-Effectiveness of ASHRAE Standard 90.1-2013 for the State of Pennsylvania.*[22]

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Energy Benefits and Costs			
Change in Electricity Consumption (GWh)	-2,282	-14,962	-7,110
Change in Natural Gas Consumption (BBtu)	-6,590	-45,144	-21,284
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	1,164,587	5,374,682	2,976,499
SO_2 Emission Reductions (MT)	1,476	4,355	3,061
NOx Emission Reductions (MT)	785	2,300	1,656
Hg Emission Reductions (MT)	0.03	0.07	0.05
Economic Benefits and Costs			
Capital Expenditures ($ Million)	$174.78	$192.53	$177.44
Fuel Savings ($ Million)	$313.10	$2,394.67	$1,087.51
Net Present Value ($)			$18,344,875,625
Cost-per-ton of GHG Emission Reductions ($/$MTCO_2e$)			-$198.52[a,b]

Notes: Positive "changes" indicate increases from business-as-usual (BAU) values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

[a] Negative cost-per-ton represents net cost savings.

[b] For this and all other actions, a discount rate of 1.75% is used and dollars are presented in as 2015 values.

[20] Pennsylvania Statewide Evaluator. (SWE). 2017. PECO Combined Incremental Cost Database v 3.1

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

[22] Pacific Northwest National Laboratory. (PNNL). 2015. Cost-Effectiveness of ASHRAE Standard 90.1- 2013 for the State of Pennsylvania. PNNL-25017. Accessed on July 3, 2018. Available at: https://www.energycodes.gov/sites/default/files/documents/Cost-effectiveness_of_ASHRAE_Standard_90-1-2013-Pennsylvania.pdf

Action: Increase adoption of energy efficiency, and expand Act 129

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- Residential
  - Energy Savings: Using the Pennsylvania Statewide Evaluator's (SWE) *Energy Efficiency Potential Study for Pennsylvania,*[23] the analysis team applies the calculated maximum achievable potential from 2021-2050 (1.5 percent). Historically, it has been seen that this is a potential that can be achieved. The analysis team assumes a measure lifetime of 10 years.
  - Cost Savings: The team takes residential hard and soft costs documented in the SWE potential study and apply them annually from 2021-2050. This includes incentive and administrative soft costs and direct capital hard costs.
- Commercial
  - Energy Savings: Again, using the SWE's study, the analysis team applies the maximum achievable potential from 2021-2025 (0.8 percent) followed by 1.0 percent annual incremental savings for years 2026-2050. The team assumes a measure lifetime of 10 years.
  - Cost Savings: The analysis team applies non-residential incentive, administrative, and direct capital costs from PA SWE annually from 2021-2050.

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Energy Benefits and Costs			
Change in Electricity Consumption (GWh)	-5,375	-9,986	-8,857
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	1,916,947	1,984,261	2,426,293
SO_2 Emission Reductions (MT)	3,941	3,580	4,895
NOx Emission Reductions (MT)	1,728	1,357	2,092
Hg Emission Reductions (MT)	0.07039	0.05	0.08
Economic Benefits and Costs			
Capital Expenditures ($ Million)	$341.26	$316.22	$338.18
Fuel Savings ($ Million)	$763.09	$1,581.64	$1,371.61
Program Costs ($ Million)[a]	$276.06	$251.45	267.54
Net Present Value ($)			$14,916,207.67
Cost-per-ton of GHG Emission Reductions ($/mt CO_2e)			-$198.31[b]

[23] Statewide Evaluation Team. 2015. Energy Efficiency Potential Study for Pennsylvania. Prepared for the Pennsylvania Public Utility Commission. Accessed on July 3, 2018. Available at: http://www.puc.pa.gov/pcdocs/1345079.pdf

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

[a] Public sector expenditures are in addition to the capital expenditures shown. This represents the administrative and incentive costs for energy efficient actions.

[b] Negative cost-per-ton represents net cost savings.

Action: Create an Act 129-like conservation and efficiency program for natural gas

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- Residential
  - Energy Savings: Using an American Council for an Energy-Efficient Economy (ACEEE) Energy Efficiency Resource Standard (EERS) policy brief,[24] the analysis team applies the Massachusetts EERS target of 1.1 percent annual incremental natural gas savings from 2020-2025 followed by 1.0 percent from 2026-2050. The team assumes a measure lifetime of 10 years.
  - Cost Savings: The team applies a $0.35/therm levelized cost of saved energy (CSE) from ACEEE's *Review of the Cost of Utility Energy Efficiency Programs*[25] annually from 2020-2050. CSE includes direct program costs like incentives, as well as measure installation, program design and administration, marketing, education, evaluation, and shareholder incentives/performance fees.
- Commercial
  - Energy Savings: The analysis team uses the same approach as residential, with savings percentages mirroring electricity.
  - Cost Savings: Again, the team uses the same approach as residential.

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Energy Benefits and Costs			
Change in Natural Gas Consumption (BBtu)	-15,883	-29,458	-25,153
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	845,010	1,567,198	1,338,143
SO_2 Emission Reductions (MT)	4	8	7
NOx Emission Reductions (MT)	653	1,211	1,034
Hg Emission Reductions (MT)	0.002	0.003	0.003

[24] American Council for an Energy Efficient Economy. (ACEEE). 2017. State Energy Efficiency Resource Standards. Accessed July 13, 2018. Available at http://aceee.org/policy-brief/state-energy-efficiency-resource-standard-activity

[25] American Council for an Energy Efficient Economy. (ACEEE). 2014. The Best Value for America's Energy Dollar: A National Review of the Cost of Utility Energy Efficiency Programs. Accessed July 13, 2018. Available at http://aceee.org/research-report/u1402

	2025	2050	Annual Average (2020 – 2050)
Economic Benefits and Costs			
Capital Expenditures ($ Million)	$25.04	$46.45	$39.66
Fuel Savings ($ Million)	$180.56	$402.41	$313.96
Program Costs ($ Million)[a]	$30.27	$52.70	$46.40
Net Present Value ($)			$4,943,581,792
Cost-per-ton of GHG Emission Reductions ($/mt CO_2e)			-$119.17[b]

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

[a] Public sector expenditures are in addition to the capital expenditures shown. This represents the administrative and incentive costs for energy efficient actions.

[b] Negative cost-per-ton represents net cost savings.

Action: Expand energy assessments and provide more trainings on energy efficiency for industry

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- Electricity
  - Energy Savings: Using the Pennsylvania Statewide Evaluator's (SWE) *Energy Efficiency Potential Study for Pennsylvania,*[26] the analysis team applies the calculated maximum achievable potential from 2020-2025 (1.2 percent) followed by the average incremental annual maximum achievable potential (1.2 percent) from 2016-2025 for years 2026-2050 for electricity.
  - Cost Savings: The analysis team applies total incentive, administrative, and direct capital costs from PA SWE[27] annually from 2021-2050
- Natural Gas
  - Energy Savings: Using a 2009 Georgia Tech meta-review of efficiency potential studies,[28] the team applies the natural gas average annual energy efficiency potential for the industrial sector of 0.6 percent from 2020-2050. The team assumes a measure lifetime of 10 years.

[26] Statewide Evaluation Team. 2015. Energy Efficiency Potential Study for Pennsylvania. Prepared for the Pennsylvania Public Utility Commission. Accessed on July 3, 2018. Available at: http://www.puc.pa.gov/pcdocs/1345079.pdf

[27] Ibid

[28] Georgia Institute of Technology. 2009. Meta-Review of Efficiency Potential Studies and Their Implications for the South. Accessed July 13, 2018. Available at: https://smartech.gatech.edu/handle/1853/30189

- Cost Savings: The analysis team applies a $0.35/therm levelized CSE from ACEEE's *Review of the Cost of Utility Energy Efficiency Programs*[29] annually from 2020-2050. CSE includes direct program costs like incentives, as well as measure installation, program design and administration, marketing, education, evaluation, and shareholder incentives/performance fees.

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Energy Benefits and Costs			
Change in Electricity Consumption (GWh)	-2,981	-6,211	-5,002
Change in Natural Gas Consumption (BBtu)	-15,781	-35,325	-26,790
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	1,901,335	3,110,031	2,786,470
SO_2 Emission Reductions (MT)	2,190	2,236	2,754
NOx Emission Reductions (MT)	1,607	2,296	2,276
Hg Emission Reductions (MT)	0.041	0.037	0.051
Economic Benefits and Costs			
Capital Expenditures ($ Million)	$518.32	$587.44	$534.31
Fuel Savings ($ Million)	$382.07	$930.66	$694.36
Program Costs ($ Million)[a]	$156.24	$183.94	$165.20
Net Present Value ($)			-$718,032,002[b]
Cost-per-ton of GHG Emission Reductions ($/mt CO_2e)			$8.31

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

[a] Public sector expenditures are in addition to the capital expenditures shown. This represents the administrative and incentive costs for energy efficient actions.

[b] 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.

Strategy: Implement sustainable transportation planning and practices

Actions include:

- Reduce vehicle miles traveled for single-occupancy vehicles
- Implement a strategic plan and incentives for increasing electric vehicle use

[29] American Council for an Energy Efficient Economy. (ACEEE). 2014. The Best Value for America's Energy Dollar: A National Review of the Cost of Utility Energy Efficiency Programs. Accessed July 13, 2018. Available at http://aceee.org/research-report/u1402

- Increase the use of clean public transportation through electric municipal bus fleets

Action: Reduce vehicle miles traveled for single-occupancy vehicles

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- VMT Reduction: The analysis team uses an overall vehicle miles traveled (VMT) reduction target of 3.4 percent by 2030 and 7.5 percent of total VMT from BAU by 2050. This estimate is based on the draft Pennsylvania Energy Assessment Report prepared in 2018,[30] as well as Pennsylvania-specific runs of the EPA's MOtor Vehicle Emission Simulator (MOVES),[31] U.S. Energy Information Administration's (EIA) *Annual Energy Outlook 2018,*[32] and Federal Highway Administration VMT projections.[33]

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Energy Benefits and Costs			
Change in Electricity Consumption (GWh)	-19	-195	-86
Change in Distillate Fuel Oil Consumption (BBtu)	-100	-546	-275
Change in Motor Gasoline Consumption (BBtu)	-7,790	-38,195	-19,582
Change in Biodiesel Consumption (BBtu)	-2.	-11	-6
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	573,260	2,820,936	1,448,026
SO_2 Emission Reductions (MT)	21	91	55
NOx Emission Reductions (MT)	731	996	790
Hg Emission Reductions (MT)	0.001	0.003	0.002
Economic Benefits and Costs			
Capital Expenditures ($ Million)	$53.04	$267.28	$136.06
Maintenance and Repair Costs ($ Million)[a]	-$251.45	-$1,263.82	-$643.85
Fuel Savings ($ Million)	$175.35	$875.06	$446.60
Net Present Value ($)			$20,114,241,585
Cost-per-ton of GHG Emission Reductions ($/mt CO_2e)			-$447.32[b]

[30] Pennsylvania Department of Environmental Protection (DEP). 2018. Draft Report: Energy Assessment Report for the Commonwealth of Pennsylvania.
[31] https://www.epa.gov/moves Accessed July 3, 2018.
[32] U.S. Energy Information Administration (EIA). 2018. Annual Energy Outlook. Accessed July 3, 2018. Available at: https://www.eia.gov/outlooks/aeo/
[33] Federal Highway Administration (FHWA). 2018. FHWA Forecasts of Vehicle Miles Traveled (VMT): Spring 2018. Accessed July 3, 2018. Available at: https://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_forecast_sum.pdf

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

[a] Negative maintenance and repair costs represent net cost savings. As fewer miles are traveled, reduced wear on vehicles results in savings on maintenance and repairs.[ba] Negative cost-per-ton represents net cost savings.

Action: Implement a strategic plan and incentives for increasing electric vehicle use

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- EV Market Penetration: The analysis team assumes EVs will represent 31 percent of the light-duty market share by 2030, rising to 88 percent by 2050. The target is based on a review of the U.S. EIA's *Annual Energy Outlook 2018* national-level projections,[34] as well as the Pennsylvania DEP report *Pennsylvania Electric Vehicle Roadmap,*[35] with consideration for the current market share.[36]
- Costs and Fuel Economy: Fuel cost, maintenance costs, and fuel economy values are based on Department of Energy (DOE) assumptions (via Argonne National Laboratory)[37] and Energy Information Administration (EIA) averages.[38,39,40] EV charging infrastructure costs are based on a review of recent literature and industry information. Projected EV passenger vehicle costs are based on EIA's *Annual Energy Outlook 2018*[41] projections as well as the National Renewable Energy Laboratory's (NREL) *Electrification Futures Study: A Technical Evaluation of the Impacts of an Electrified U.S. Energy System.*[42] Bloomberg New Energy Finance cost forecasts[43] were also evaluated and considered for reference.

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[34] U.S. Energy Information Administration (EIA). 2018. Annual Energy Outlook. Accessed July 3, 2018. Available at: https://www.eia.gov/outlooks/aeo/

[35] Pennsylvania Department of Environmental Protection. (DEP). 2018. Pennsylvania Electric Vehicle Roadmap. *In Draft Final Stages as of November 21, 2018.*

[36] Level 1 equipment it's less expensive, but it is likely not going to receive much public funding as it is focused on residential and some businesses. Additionally, as batteries get bigger/ranges get longer, Level 1 likely will not be able to meet the technical requirements. Much of the market share and focus is on Level 2 equipment.

[37] ANL. 2017. AFLEET Tool. Accessed July 3, 2018. Available at: https://greet.es.anl.gov/afleet_tool

[38] U.S. EIA. 2018. Annual Energy Outlook 2018. Accessed July 3, 2018. Available at: https://www.eia.gov/outlooks/aeo/

[39] U.S. EIA. 2018. Weekly Retail Gasoline and Diesel Prices. Accessed July 3, 2018. Available at: https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_r1y_a.htm

[40] U.S. EIA. 2018. Pennsylvania State Profile and Energy Estimates. Accessed July 3, 2018. Available at: https://www.eia.gov/state/rankings/?sid=PA#series/31

[41] U.S. EIA. 2018. Annual Energy Outlook. Accessed July 3, 2018. Available at: https://www.eia.gov/outlooks/aeo/

[42] NREL. 2018. Electrification Futures Study: A Technical Evaluation of the Impacts of an Electrified U.S. Energy System. Accessed July 3, 2018. Available at: https://www.nrel.gov/analysis/electrification-futures.html

[43] Bloomberg New Energy Finance. 2017. The Electric Car Revolution Is Accelerating. Available at: https://www.bloomberg.com/news/articles/2017-07-06/the-electric-car-revolution-is-accelerating

- State Funding: The analysis team estimates that state funding for infrastructure will be $1.6 million per year from 2019 to 2028 based on the VW settlement funds of $16 million. These annual levels are estimated with consideration of historical state funding for EV charging infrastructure, including Pennsylvania's Alternative Fuels Inventive Grant Program (AFIG)[44] and other state deployment projects (e.g., Pennsylvania Turnpike). This estimate is used as an input for the REMI model.
    - Pennsylvania's Alternative Fuels Incentive Grant program has been the primary source of state funding for EV charging stations as well as vehicles. $5M is available for 2018, but only a portion of that has been routed to EVs and charging infrastructure. The team understands that $1M is set aside for alternative fuel infrastructure of all types, including EV charging and can generally estimate that approximately $1.5-2M per year (for the last few years) has been allocated to EVs and infrastructure.
    - This analysis does not include any federal funding, which, if available, would improve the economic case for purchasing EVs.

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Energy Benefits and Costs			
Change in Electricity Consumption (GWh)	1,310	41,736	16,434
Change in Distillate Fuel Oil Consumption (BBtu)	-160	-5,788	-2,256
Change in Motor Gasoline Consumption (BBtu)	-12,951	-411,724	-162,144
Change in Biodiesel Consumption (BBtu)	-3	-118	-46
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	474,100	21,689,937	7,694,504
SO_2 Emission Reductions (MT)	-949	-14,735	-8,012
NOx Emission Reductions (MT)	782	4,761	1,926
Hg Emission Reductions (MT)	-0.02	-0.20	-0.13
Economic Benefits and Costs			
Capital Expenditures ($ Million)	$1,927.83	$5,664.45	$3,556.81
Maintenance and Repair Costs ($ Million)	-$49.90	-1,597.41	-$628.72
Fuel Savings ($ Million)	$108.40	$3,450.53	$1,358.73
Net Present Value ($)			-$35,983,465,661[a]
Cost-per-ton of GHG Emission Reductions ($/mt CO_2e)			$150.85

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

[a] 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

[44] http://www.envirothonpa.org/documents/22fAFIG.pdf Accessed on July 4, 2018.

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.

Action: Increase the use of clean public transportation through electric municipal bus fleets

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- New EV Bus Purchases: The analysis team assumes that 25 percent of new municipal transit bus purchases will be zero emission buses, specifically battery electric, by 2030, increasing to 60 percent by 2050. This projection is based on zero emission transit bus market penetration projections from CALSTART[45] as well as various state targets. While hydrogen buses may also prove feasible in the long-term, battery electric buses are likely to dominate the zero-emission bus market in Pennsylvania due to technology maturity, relatively lower low life cycle costs and environmental benefits.[46]
- Costs and Fuel Economy: Fuel costs, maintenance costs, and fuel economy values are based on U.S. Department of Energy (DOE) assumptions (via Argonne National Laboratory)[47] and U.S. EIA averages.[48,49,50] Electric transit bus and charging infrastructure costs are based on a review of

[45] CALSTART. 2015. Electric Truck & Bus Grid Integration: Opportunities, Challenges & Recommendations. Accessed July 3, 2018. Available at: http://www.calstart.org/Libraries/Publications/Electric_Truck_Bus_Grid_Integration_Opportunities_Challenges_Recommendations.sflb.ashx

[46] Carnegie Mellon University (CMU) Scott Institute for Energy Innovation. 2016. Policymaker Guide: Which Alternative Fuel Technology is Best for Transit Buses?. Accessed July 15, 2018. Available at: https://www.cmu.edu/energy/education-outreach/public-outreach/17-104%20Policy%20Brief%20Buses_WEB.pdf

[47] Argonne National Laboratory (ANL). 2017. Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool. Accessed July 3, 2018. Available at: https://greet.es.anl.gov/afleet_tool

[48] U.S. EIA. 2018. Annual Energy Outlook 2018. Accessed July 3, 2018. Available at: https://www.eia.gov/outlooks/aeo/

[49] U.S. EIA. 2018. Weekly Retail Gasoline and Diesel Prices. Accessed July 3, 2018. Available at: https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_r1y_a.htm

[50] U.S. EIA. 2018. Pennsylvania State Profile and Energy Estimates. Accessed July 3, 2018. Available at: https://www.eia.gov/state/rankings/?sid=PA#series/31

recent literature and industry information.[51,52,53,54,55,56,57] This analysis does not include any state or federal incentive funding, which, if available, would significantly improve the economic case for purchasing zero emission buses.

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Energy Benefits and Costs			
Change in Electricity Consumption (GWh)	38	872	301
Change in Distillate Fuel Oil Consumption (BBtu)	-330	-7,543	-2,604
Change in Natural Gas Consumption (BBtu)	-57	-1,356	-465
Change in Biodiesel Consumption (BBtu)	-7	-154	-53
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	13,948	458,048	142,951
SO_2 Emission Reductions (MT)	-27	-306	-145
NOx Emission Reductions (MT)	93	1,453	496
Hg Emission Reductions (MT)	-0.00004	0.00576	0.00106
Economic Benefits and Costs			
Capital Expenditures ($ Million)	$97.32	$442.34	$238.37
Maintenance and Repair Costs ($ Million)	-$0.70	-$15.02	-$5.30
Fuel Savings	$2.71	$57.76	$20.38
Net Present Value ($)			-$4,527,294,366[a]
Cost-per-ton of GHG Emission Reductions ($/mt CO_2e)			$1,021.53

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

[a] 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.

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[51] Tyggestad, C., N. Sharma, J. van de Staaij, and A. McKinsey Energy Institute. 2017. Keizer, New Reality: Electric Trucks and their Implications on Energy Demand

[52] California Air Resources Board (CARB). 2015. Draft Technology Assessment: Medium- and Heavy-Duty Fuel Cell Electric Vehicles. Available at: https://www.arb.ca.gov/msprog/tech/techreport/fc_tech_report.pdf

[53] Eudy, L. and M. Jeffers. National Renewable Energy Laboratory (NREL). 2017. Foothill Transit Battery Electric Bus Demonstration Results: Second Report. Available at: https://www.nrel.gov/docs/fy17osti/67698.pdf

[54] Swanton, A. BYD. 2017. The Pathway to Battery Electric. Presentation.

[55] Chandler, S., J. Espino, and J. O'Dea. Union of Concerned Scientists and The Greenlining Institute. 2017. Delivering Opportunity: How Electric Buses and Trucks Can Create Jobs and Improve Public Health in California. Available at: https://www.ucsusa.org/sites/default/files/attach/2016/10/UCS-Electric-Buses-Report.pdf

[56] CARB. 2015. Draft Technology Assessment: Medium- and Heavy-Duty Battery Electric Trucks and Buses. Available at: https://www.arb.ca.gov/msprog/tech/techreport/bev_tech_report.pdf

[57] CARB. 2017. Innovative Clean Transit. Available at: https://arb.ca.gov/msprog/ict/ict.htm

Sector: Energy Production

Strategies include:

- Increase use of clean, distributed electricity generation resources
- Create a diverse portfolio of clean, utility-scale electricity generation
- Reduce impacts of fossil fuel energy production and distribution
- Increase production and use of alternative fuels

Strategy: Increase use of clean, distributed electricity generation resources

Actions include:

- Invest in and promote building-scale solar
- Incentivize and increase use of combined heat and power

Action: Invest in and promote building-scale solar

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- Energy: The analysis team uses information from the *Finding Pennsylvania's Solar Future Plan (PA Solar Future)*.[58] In this Plan, the building-scale solar is 10 percent of total solar development, as outlined in the Plan's Scenario B, and building-scale solar capacity is split evenly between residential and commercial. System costs are taken from the *PA Solar Future* study which come from the 2017 National Renewable Energy Laboratory (NREL) Annual Technology Baseline Data; residential system costs are assumed to fall from $2.40/watt in 2020 to $1.15/watt in 2050, while commercial system costs are assumed to fall from $1.78/watt in 2020 to $0.97/watt in 2050.

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Energy Benefits and Costs			
Change in Electricity Consumption (GWh)	0	-243	-208
Change in Renewable Energy Capacity (MW)	0	69	4

[58] Pennsylvania Department of Environmental Protection (PA DEP). 2018. Finding Pennsylvania's Solar Future Plan. Accessed July 3, 2018. Available at: http://www.dep.pa.gov/Business/Energy/OfficeofPollutionPrevention/SolarFuture/Pages/Finding-Pennsylvania%E2%80%99s-Solar-Future.aspx

	2025	2050	Annual Average (2020 – 2050)
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	-	48,210	55,279
SO_2 Emission Reductions (MT)	-	87	111
NOx Emission Reductions (MT)	-	33	47
Hg Emission Reductions (MT)	-	0.001	0.002
Economic Benefits and Costs			
Capital Expenditures ($ Million)	$0.00	-$2.34	$28.56
Maintenance and Repair Costs ($ Million)	$0.00	$0.60	$0.00
Fuel Savings ($ Million)	$0.00	$34.94	$0.71
Net Present Value ($)			$489,952,564
Cost-per-ton of GHG Emission Reductions ($/mt CO_2e)			-$285.11[a]

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

[a] Negative cost-per-ton represents net cost savings.

Action: Incentivize and increase use of combined heat and power

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- Preferential Rate Incentive: Efficient combined heat and power (CHP) systems are assumed to receive a preferential retail natural gas rate of $5 per MMBtu, escalating according to BAU natural gas growth rates through 2050. The preferential natural gas rate is similar to natural gas rates offered to CHP customers through New York and California investor-owned utilities (IOUs). While current natural gas rates are lower, given the timeframe of this analysis a $5 price is assumed as the ceiling price for which CHP would remain competitive. This action will improve project economics and encourage greater deployment of utility-scale industrial CHP installations as well as CHP systems under 20 MW in size. The analysis team uses 20 MW as the threshold in line with other related work conducted, such as for the DOE report *Combined Heat and Power (CHP) Technical Potential in the United States*.[59] Potential host sites for utility-scale CHP in Pennsylvania are identified in ICF's CHP Database.[60] The analysis team estimates payback periods for each potential project using cost and performance assumptions, based on system

[59] Department of Energy. (DOE). 2016. Combined Heat and Power (CHP) Technical Potential in the United States. DOE/EE-1328. Accessed July 15, 2018. Available at: https://www.energy.gov/sites/prod/files/2016/04/f30/CHP%20Technical%20Potential%20Study%203-31-2016%20Final.pdf

[60] ICF. Combined Heat and Power Database. Proprietary. Accessed July 3, 2018.

sizes, from the previous analysis for the draft Pennsylvania Energy Assessment Report prepared in 2018.[61]

- Energy: While most CHP systems use natural gas, they are substantially more efficient than separate heat and utility-delivered electricity. With the improved efficiency, there is a net reduction in fossil fuel consumption when CHP is implemented.
    - >20 MW: With utility-scale CHP defined as CHP applications 20 MW or larger in size, the business-as-usual case relies on the assumption that all high load factor sites have economic potential, with about one-third of the full potential annualized through 2030, and a phase-out of annual installations from 2031 to 2035 as the electricity grid gets cleaner and CHP becomes a less effective mitigation option. The incentive appears to have a marginal effect on economics for sites supporting >20 MW CHP, as $5/MMBtu is not significantly lower than the BAU natural gas rate. However, the $5/MMBtu natural gas rate did push one large low load factor site–the City of Philadelphia government building complex–into economic territory. Overall, an additional 636 MW of utility-scale CHP is expected through 2050, compared to the BAU case, and the economic incentive would only have a marginal effect on the annualized numbers.
    - <20MW: For CHP at large campuses, hospitals, and industrial buildings, the team expects an increase in end-use natural gas consumption coupled with a decrease in end-use electricity consumption as a result of sites producing their own power and heat with CHP. Savings from utility transmission and distribution losses are estimated based on eGrid factors from EPA's State Inventory Tool (SIT). With natural gas costs starting at $5/MMBtu, economics for CHP are greatly improved for smaller applications. All potential CHP sites for high load factor applications under 20 MW in size—identified from ICF's CHP Technical Potential Database—would have economic potential for CHP. Additionally, some low load factor applications in the 500-999 kW size range become economical with the $5/MMBtu natural gas rate. Overall, this represents an increase of 1.8 GW of economic potential compared to the BAU case, which would be primarily installed from 2020 to 2030, with installations slowing from 2031 to 2035 as the electricity grid gets cleaner and CHP becomes a less effective mitigation option. The increase would likely start in 2020, as CHP projects generally take two years to go from planning to commissioning and operation.

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Energy Benefits and Costs			
Change in Grid-supplied Electricity Consumption (GWh)	-7,855	-17,618	-14,075
Change in Natural Gas Consumption (BBtu)	42,448	95,191	127,243

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

	2025	2050	Annual Average (2020 – 2050)
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	544,502	-1,561,128	-209,176
SO_2 Emission Reductions (MT)	5,695	6,169	7,605
NOx Emission Reductions (MT)	619	-1,881	-106
Hg Emission Reductions (MT)	0.10	0.08	0.12
Economic Benefits and Costs			
Capital Expenditures ($ Million)	$327.12	$0.00[a]	$135.68
Maintenance and Repair Costs ($ Million)	$103.50	$232.69	$185.81
Fuel Savings ($ Million)	$577.72	$1,181.75	$1,012.83
Net Present Value ($)			$7,295,090181
Cost-per-ton of GHG Emission Reductions ($/mt CO_2e)			NA[b]

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

[a] Due to projected natural gas cost increases, economics for CHP installations are expected to become unfavorable in the mid-2030s. Because the forecasted adoption is based purely on economic decision-making, no new installations are modeled after 2035. Other factors, however, could influence future CHP build decisions, such as increased reliability and resiliency.

[b] Because (CHP) is projected to result in a net increase in GHG emissions by 2050 when using an average emission factor to calculate GHG reductions, a reduction cost per ton is not an applicable metric as it does not allow for a consistent comparison of costs per ton across the various strategies and actions. GHG emissions reduced through electricity savings are counter-balanced by GHG emissions resulting from increased natural gas use. In this modeling analysis, that point occurs during the 2040s. However, when looking at emission reductions based on marginal emission factors, GHG reductions from CHP are positive across the entire time series through 2050, although they taper significantly at the end of the time series. Note: the team looked at the impacts from new natural gas combustion in new CHP systems and did not quantify the potential from using bottoming cycle CHP to capture waste heat from existing combustion systems, which was beyond the scope of this analysis.

Depending on the scope and resources for an analysis, higher level climate action planning efforts can rely on an average grid emission factor. This is typically used in analysis to ensure consistency in how results are being discussed and framed, and since climate action plans are generally looking to set expectations on order of magnitude of emission reductions, or indications of level of reductions. Moreover, in some cases and depending on the region of the country, the difference between a marginal and average emissions factor will continue to shrink over time. However, this methodology undervalues the actual emissions savings benefits of CHP according to CHP and energy calculation guidance from EPA: https://www.epa.gov/sites/production/files/2015-07/documents/fuel_and_carbon_dioxide_emissions_savings_calculation_methodology_for_combined_heat_and_power_systems.pdf

When analyzing electricity generation changes and resulting changes in emissions over time, it is important to understand that electric generation sources are "dispatched" by their system operators (which is PJM for PA) in a standard priority order. All "must run" units are dispatched first so that they always operate when available, then intermediate fossil fuel generation is dispatched, with fossil

peaking generation dispatched last. Must run units include nuclear and utility-scale renewable sources, which are carbon-free sources of power.

A distributed resource like CHP will consistently reduce the demand for electricity from central station plants. When looking at which electric generation sources would actually be shut off or ramped down as electric demand decreases, it is the marginal generation units that are ramped down. During peak daytime hours this is peaking capacity that typically comes from natural gas or oil simple cycle units. During off-peak hours, the utility is likely to turn down intermediate fossil fuel resources like combined cycle natural gas and coal-fired plants in response to lower demand. Since nuclear, hydro, and other renewable generation are must-run sources and will not actually be shut off or ramped down when electric demand decreases, according to EPA guidance they should not be included in the emission factor used to calculate emissions reductions from CHP. In lieu of being able to do specific load curve analyses, the guidance recommends a marginal generation emission factor be used to calculate emission reductions from CHP use as opposed to an average grid emission factor. All of the CHP systems that showed economic potential in Pennsylvania were high load factor applications that would utilize electricity and thermal energy from CHP 24 hours a day, 7 days a week. As such, the EPA recommended method for estimating marginal utility emission reductions would be to use the eGRID fossil fuel emissions factor.

The marginal emission factor for the purposes of the alternative CHP GHG reduction calculation was completed as follows:

- The analysis team considered an emission factor that only takes into account fossil fuel generation and not the entire grid mix (i.e., ignores power generation from carbon-free sources). This is essentially a proxy for the marginal emission factor.
- The analysis team started with the eGRID fossil emission factors in 2015, and then adjusted this emission factor over time to 2050 to account for changes in the fossil fuel generation mix (including natural gas, coal, and fuel oil).
    - To adjust the emission factor over time the analysis looked at the change in mix of fossil fuels over time (lower carbon content NG will increase in use while higher carbon content coal will decrease). The change in grid mix was calculated as part of the overall CAP calculations, including the change in fossil fuel use for power generation over time through 2050.

Long term contributions of CHP to GHG emission reductions is a continually evolving research and analysis area given that more ambitious renewable generation targets are being set and natural gas combined cycle generation continues to increase in use. This is an area worth future, more detailed study and investigation.

Strategy: Create a diverse portfolio of clean, utility-scale electricity generation

Actions include:

- Increase Alternative Energy Portfolio Standard(AEPS) Tier 1 targets, and further increase in-state generation and use of renewables
- Implement policy to maintain nuclear generation at current levels
- Limit carbon emissions through an electricity sector cap and trade program

Action: Increase AEPS Tier 1 targets, and further increase in-state generation and use of renewables

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- Energy: The analysis team increases AEPS requirements from eight percent Tier 1 renewables by 2020 (2020-2021 year) to 30 percent Tier 1 by 2030 and 50 percent by 2050 with a six percent solar carve out phased in linearly to 2030.[62] These increases are in line with what the analysis team found for other states and represent an ambitious target.[63] More specifically:
    - The solar carve out is in line with *Finding Pennsylvania's Solar Future Plan*.[64]
    - Generation for wood/wood waste solids, low impact hydro, black liquor, coal mine methane and other biogas from 2017 through 2050 was developed based on the Lawrence Berkeley National Lab's (LBNL) report *Renewables Portfolio Standards: 2017 Annual Status Report:*[65] If these resources are developed through other strategy actions (e.g., Promote the production and use of alternative fuels), the related impacts are built into this AEPS action.
    - Wind is scaled up to make up the difference between total Tier 1 generation and the sum of the solar and other non-solar Tier 1 resources.[66]
    - All future solar Alternative Energy Credits (AECs) are closed to Pennsylvania borders through 2050. This assumption is based on the Pennsylvania House Bill 118, 2017 Act 40 published on October 30, 2017).[67]
- Costs: The analysis team relies on cost data from the National Renewable Energy Laboratory's (NREL) 2017 Annual Technology Baseline Data,[68] using the mid-cost scenario for utility-scale solar, building-scale solar, and wind. These data are also used in *Finding Pennsylvania's Solar*

[62] The solar carve out means that solar must account for 6% of utility sales by 2030. This percentage is phased in from 2020 to 2030 in equal annual increments. The AEPS solar carve out in the Pennsylvania Solar Futures Study (PASF) remained between 4 and 8 percent; a 6 percent AEPS solar carve out was deemed a feasible and appropriate option by the PASF stakeholder group.

[63] ICF reviewed renewable energy policies from New Jersey, Delaware, Maryland, District of Columbia, North Carolina, Michigan, Ohio, Illinois, New York, California, Oregon, and Rhode Island. This list captures the PJM Region states as well as states that are likely the most ambitious in their renewable policies. Lawrence Berkeley National Lab (LBNL). 2017. U.S. Renewables Portfolio Standards: 2017 Annual Status Report. Accessed July 3, 2018. Available at: https://emp.lbl.gov/publications/us-renewables-portfolio-standards-0

[64] Pennsylvania Department of Environmental Protection (PA DEP). 2018. Finding Pennsylvania's Solar Future Plan. Accessed July 3, 2018. Available at: http://www.dep.pa.gov/Business/Energy/OfficeofPollutionPrevention/SolarFuture/Pages/Finding-Pennsylvania%E2%80%99s-Solar-Future.aspx

[65] Lawrence Berkeley National Lab (LBNL). 2017. U.S. Renewables Portfolio Standards: 2017 Annual Status Report. Accessed July 3, 2018. Available at: https://emp.lbl.gov/publications/us-renewables-portfolio-standards-0

[66] The team also assumes that wind (and other AEPS generating sources) are being produced in-state.

[67] Pennsylvania House Bill 118, 2017 Act 40. Accessed on July 3, 2018. Available at: http://www.legis.state.pa.us/cfdocs/legis/li/uconsCheck.cfm?yr=2017&sessInd=0&act=40

[68] National Renewable Energy Laboratory (NREL). 2017. Annual Technology Baseline. Accessed July 3, 2018. Available at: https://atb.nrel.gov/

Future Plan. The wind cost scenario was chosen based on the 30 percent statewide capacity factor indicated in the LBNL *Renewables Portfolio Standards: 2017 Annual Status Report.*[69]

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Energy Benefits and Costs			
Change in Renewable Energy Generation (GWh)	13,867	58,725	34,149
Change in Renewable Energy Capacity (MW)	6,496	24,486	14,849
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	10,532,686	51,422,405	28,007,231
Target-Related GHG Emission Reductions ($MTCO_2e$)[a]	6,703,719	27,639,941	16,108,474
SO_2 Emission Reductions (MT)	12,770	76,275	17,475
NOx Emission Reductions (MT)	6,100	34,217	17,475
Hg Emission Reductions (MT)	0.3	1.4	0.7
Economic Benefits and Costs			
Capital Expenditures ($ Million)	$1,949.16	$1,126.74	$1,202.80
Maintenance and Repair Costs ($ Million)	$89.47	$156.55	$160.66
Fuel Savings ($ Million)	$337.12	$1,557.02	$879.20
Net Present Value ($)			-$13,550,651,044[b]
Cost-per-ton of GHG Emission Reductions ($/mt CO_2e)			$27.13

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

[a] Target-related GHG emission reductions represent the portion of emission reductions associated with in-state electricity consumption. This metric is shown only for actions that affect Pennsylvania's electricity generation fuel mix since these result in additional GHG emission reductions that are not accounted for within the commonwealth (i.e., emissions associated with generated electricity that is exported and consumed outside of Pennsylvania). For actions that do not affect the grid, 100 percent of total GHG emission reductions are counted toward the target.

[b] 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.

[69] Lawrence Berkeley National Lab (LBNL). 2017. U.S. Renewables Portfolio Standards: 2017 Annual Status Report. Accessed July 3, 2018. Available at: https://emp.lbl.gov/publications/us-renewables-portfolio-standards-0

Action: Implement policy to maintain nuclear generation at current levels

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- Energy: For the BAU, the analysis team assumes that as announced Three Mile Island closes in 2019 and Beaver Valley closes in 2021.[70] BAU nuclear generation levels are held constant after these plants are closed.[71] To model a policy action that restores these units to service for the study period, their capacity and generation are added back to the PJM fleet. To balance the overall electricity generation totals over the years (i.e., to not create new generation on top of the business-as-usual scenario), the team assumed that nuclear electricity generation displaces coal and natural gas electricity generation in future years.
- Costs: Operating and maintenance costs are based on EPA's Base Case for the Integrated Planning Model and include fixed and variable operation and maintenance (O&M) costs associated with increased nuclear generation and capacity as well as O&M savings from reduced natural gas and coal electricity generation. Potential for uprates to existing facilities in PA were not considered.

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	28,928,575	39,353,499	29,677,777
Target-Related GHG Reductions ($MTCO_2e$)[a]	18,412,115	21,152,811	17,526,325
SO_2 Emission Reductions (MT)	35,974	36,267	33,548
NOx Emission Reductions (MT)	16,755	24,605	17,303
Hg Emission Reductions (MT)	0.7	1.0	0.7
Economic Benefits and Costs			
Maintenance and Repair Costs ($ Million)	$843.72	$1,136.27	$879.46
Fuel Savings ($ Million)	$248.14	$267.79	$242.69
Net Present Value ($)			-$14,463,164,164[b]
Cost-per-ton of GHG Emission Reductions ($/mt CO_2e)			$26.31

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

[a] Target-related GHG emission reductions represent the portion of emission reductions associated with in-state electricity consumption. This metric is shown only for actions that affect Pennsylvania's electricity generation fuel

[70] http://www.businessinsider.com/three-mile-island-nuclear-plant-closing-2017-5 and https://www.bizjournals.com/pittsburgh/news/2018/03/28/firstenergy-announces-plans-to-close-beaver-valley.html Accessed July 3, 2018.

[71] This BAU is different than what is represented in the recent draft report *Commonwealth of Pennsylvania Energy Assessment Report.* In the BAU in Energy Assessment report, only the Three Mile Island closure was accounted for; the Beaver Valley closure was announced after the analysis for the Energy Assessment was completed.

mix since these result in additional GHG emission reductions that are not accounted for within the commonwealth (i.e., emissions associated with generated electricity that is exported and consumed outside of Pennsylvania). For actions that do not affect the grid, 100 percent of total GHG emission reductions are counted toward the target.

[b] 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.

Action: Limit carbon emissions through an electricity sector cap and trade program

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- Carbon Limit: The analysis team establishes a carbon emission limit for each year, modeling a 30 percent reduction from 2020 carbon dioxide (CO_2) levels by 2030. The team assumes that the post-2030 emissions cap would phase out most remaining higher emissions sources of generation other than waste coal by 2050. Both the AEPS expansion and maintaining current levels of nuclear generation contribute to meeting the emission reductions target set by the power sector carbon cap and trade action. Remaining reductions needed are met through the abatement actions described here.
- Abatement Actions: Carbon abatement is modeled as two steps, which when combined are sufficient to meet the modeled carbon limit. These steps include:
    - *Step 1*: Natural gas dispatch is increased up to 75 percent utilization, while coal generation drops an equivalent amount. This decrease in coal generation is a result of coal retirements.
    - *Step 2* (if the emissions decreases in step 1 are insufficient to meet the emission limit in a given year): Coal generation decreases until the CO_2 limit is met, and this decrease in coal generation is taken out of Pennsylvania exports. As in step 1, decreases in coal generation are modeled as a result of coal retirements.
- Carbon Price: Each abatement action has an associated marker carbon price derived based on relative levelized cost of electricity (LCOE) calculations.[72] In other words, the carbon prices are designed to achieve the cap selected for modeling purposes (see above); the carbon price would reduce the cost-competitiveness of coal relative to natural gas, which is the incremental step beyond the AEPS that is needed to meet carbon limits and overall GHG reduction targets used

[72] The marker carbon price is derived by comparing the LCOE of lower-emitting vs. higher-emitting generation technologies; e.g. a carbon price of X would be enough to make lower-emitting generator A economically competitive with higher-emitting generator B.

for this modeling exercise.[73] The carbon price is estimated to be $1.00 per metric ton of CO_2 equivalent from 2021 through 2050.

- Carbon Revenue Recycling: Revenues from the cap and trade program are modeled in REMI as a simple payment to electricity consumers to offset the cost of the program.

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	7,697,521	0	4,972,721
Target-related GHG Emission Reductions ($MTCO_2e$)[a]	4,899,227	0	3,035,130
SO_2 Emission Reductions (MT)	9,572	0	5,955
NOx Emission Reductions (MT)	9,131	0	5,773
Hg Emission Reductions (MT)	0.4	0	0.2
Economic Benefits and Costs			
Maintenance and Repair Costs ($ Million)	-$242.46	$0.00	-$197.97
Fuel Savings ($ Million)	-$616.34	$0.00	-$404.31
Net Present Value ($)			-$5,174,461,283
Cost-per-ton of GHG Emission Reductions ($/mt CO_2e)			$55.00[b]

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

[a] Target-related GHG emission reductions represent the portion of emission reductions associated with in-state electricity consumption. This metric is shown only for actions that affect Pennsylvania's electricity generation fuel mix since these result in additional GHG emission reductions that are not accounted for within the commonwealth (i.e., emissions associated with generated electricity that is exported and consumed outside of Pennsylvania). For actions that do not affect the grid, 100 percent of total GHG emission reductions are counted toward the target.

[b] Negative cost-per-ton represents net cost savings.

Strategy: Reduce impacts of fossil fuel energy production and distribution

Actions include:

- Implement policies and practices to reduce methane emissions across natural gas systems

[73] The carbon price used for the cap and trade program is not equivalent to a social cost of carbon, which is aimed at valuing the climate impact of GHG emissions (i.e., the cost of levelized damages over the lifetime of the emissions).

Action: Implement policies and practices to reduce methane emissions across oil and natural gas systems

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- Emissions and BAU Reduction Baseline:
    - To establish an initial source level baseline, the analysis team utilized a study performed by Environmental Defense Fund (EDF)[74] which characterized upstream oil and natural gas emissions by determining cumulative source level emission and reduction estimates in future years under various regulation scenarios. The "DEP provided" cumulative emissions baseline from the study ("No Control" scenario, Short Term (2018-2020)) is considered in this analysis for both new and existing sources. Specific to this analysis, DEP-provided cumulative reduction percentages are used to generate BAU reductions for each source to provide revised 2020 cumulative emission and reduction estimates. These percentages represent the impact of complying with both federal and state level regulation of methane emitting upstream oil and natural gas sources.
    - Cumulative source level estimates are annualized using an iterative process which considers the 2020 cumulative existing and new emission "target" results, Energy Information Administration (EIA) Annual Energy Outlook (AEO) projections of oil and natural gas production (see discussion below),[75] and a decreasing trend in applicable reduction. Reduction effectiveness is assumed to decrease over time as regulation requirements are met. Existing sources have an annual assumed turnover rate (i.e., retirement and replacement with new activity to account for missing capacity). All retired existing sources are considered replaced regardless of whether overall production has decreased in a future year. Retirements are included as new sources with appropriate compliance to BAU regulations per DEP input. EDF new source 2020 cumulative result "targets" are also adjusted with respect to existing source turnover rates from 2015 to 2020.
    - Because DEP estimates are provided for unconventional sources only, conventional estimates are assumed to match that of unconventional sources per DEP input. Downstream emissions estimates are provided by EPA State Inventory Tool (SIT)[76] results and are projected from 2015 to 2050 using EIA AEO 2017 reference case natural gas consumption.[75] All upstream results generated in this analysis are scaled to match upstream SIT estimates to give appropriate segment proportions and to match Task 1 BAU case estimates.
- Annualization and Projection of Emission and Reduction Results:
    - Energy Information Administration (EIA) Annual Energy Outlook (AEO) 2017 reference case oil and natural gas production values[75] are used to both annualize source level results for 2015-2020 and project 2020 estimates to 2050. Certain sources are driven

[74] Environmental Defense Fund. (EDF). "Explore Pennsylvania's oil and gas pollution", https://www.edf.org/energy/explore-pennsylvanias-oil-and-gas-pollution
[75] U.S. Energy Information Administration. (EIA). Annual Energy Outlook (AEO) 2017. https://www.eia.gov/outlooks/archive/aeo17/
[76] U.S. Environmental Protection Agency. (EPA). State Inventory and Projection Tool. https://www.epa.gov/statelocalenergy/download-state-inventory-and-projection-tool

using forecasted natural gas production, while others are driven using a combination of oil/natural gas production (combined BTU). AEO estimates utilized in this are analysis are representative of the Middle Atlantic and East supply regions respectively. Natural gas prices used when determining recovered revenue as discussed below are also representative of the East supply region. BAU reductions in future years are determined by applying a reduction percentage to projected source level emission estimates.

- Voluntary Reductions and Associated Costs:
    - Voluntary reductions are determined by source using assumed applicability (e.g., technical limitations may exist at certain sites), reduction effectiveness, and incentive for an operator replace an existing source. Each of the above assumptions by source are based on ICF input. The analysis team assumed operator incentive to reach full applicability by 2050. Voluntary reduction volumes are determined by applying these assumptions to both existing emissions source and new sources which are not controlled through compliance with BAU regulations.
    - Capital and operating costs are determined using the voluntary reduction volume as determined above with an associate reduction per activity. This determines a number of required actions (and associated capital and operating cost) to account for the appropriate volume of voluntary reductions for each source. Recovered revenue is also calculated using voluntary reduction volumes as determined above for activities where capture is possible. An upstream natural gas composition of 78.8% methane is considered when determining recovered revenue.

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	104,879	29,598	70,913
SO_2 Emission Reductions (MT)	0	0	0
NOx Emission Reductions (MT)	0	0	0
Hg Emission Reductions (MT)	0	0	0
Economic Benefits and Costs			
Capital Expenditures ($ Million)	$2.51	$5.49	$3.71
Maintenance and Repair Costs ($ Million)	$0.52	$1.23	$0.81
Net Present Value ($)			-$58,851,222
Cost-per-ton of GHG Emission Reductions ($/mt CO_2e)			$18.70

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

Strategy: Increase production and use of alternative fuels

Actions include:

- Increase recovery and use of gas from coal mines, agriculture, wastewater, and landfills for energy

Action: Increase recovery and use of gas from coal mines, agriculture, wastewater, and landfills for energy

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- Coal Mine Methane
    - Energy Production and Consumption: The analysis team assumes that the full economic potential, estimated in the draft Pennsylvania Energy Assessment Report prepared in 2018,[77] is realized each year through 2050. The team assumes that all production is provided to natural gas pipelines and that production does not result in any additional natural gas consumption in PA.
    - Emission Reductions: Expected greenhouse gas emission reductions are calculated using the Coal Module from EPA's State Inventory Tool (SIT).[78] The team assumes that captured methane would otherwise be vented and can therefore subtract the project methane production from total coal mining emissions for the commonwealth, as projected by the SIT through 2050.
    - Costs: The team relies on estimates from the U.S. Environmental Protection Agency's (EPA) *Global Mitigation of Non-CO_2 Greenhouse Gases, 2010-2030* report for project capital expenditures.[79] The analysis team assumes that additional capital costs are incurred based on the average production of methane per mine in the BAU scenario. Based on projected production, the team estimates an additional three projects would be developed between 2018 and 2050, costing approximately $8.6 million per project. The team relies on operation and maintenance cost estimates from EPA's Coal Mine Methane Project Cash Flow Model Version 3.[80]
- Agriculture Waste, Landfill Gas, and Wastewater
    - AEPS Support: The analysis team estimates expected AEC prices based on the historic relationship between the stringency of the AEPS Tier 1 targets and average prices, as reported by the Pennsylvania Public Utility Commission (PUC). Assuming a ramp up schedule consistent with the action discussed above, the team estimates AEC prices through 2050, with the ACP price ($45/MWh) under current law acting as a ceiling. The team assumes that this serves as an additional incentive when determining project payback periods, accelerating deployment rates.
    - Costs: Capital expenditures plus operation and maintenance costs are based on estimates provided by the Oak Ridge National Laboratory's *Combined Heat and Power*

[77] Pennsylvania Department of Environmental Protection (DEP). 2018. Draft Report: Energy Assessment Report for the Commonwealth of Pennsylvania.
[78] https://www.epa.gov/statelocalenergy/download-state-inventory-and-projection-tool Accessed on July 3, 2018.
[79] United States Environmental Protection Agency. (USEPA). 2013. Global Mitigation of Non-CO_2 Greenhouse Gases: 2010-2030. EPA-430-R-13-011. Accessed July 3, 2018. Available at: https://www.epa.gov/sites/production/files/2016-06/documents/mac_report_2013.pdf
[80] https://www.epa.gov/cmop/cmm-cash-flow-model Accessed on July 3, 2018.

Market Potential for Opportunity Fuels report.[81] These are consistent with assumptions used in the Energy Assessment Report.

- Energy Savings: Renewable energy generation is expected to increase as a result of added capacity; this increase in renewable energy is modeled as a displacement of electricity consumption from the grid. We also estimate a decline in natural gas consumption resulting from displaced thermal output caused by the additional CHP deployment for wastewater and agricultural applications, while additional landfill applications are expected to only increase electricity generation from landfill gas. The amount of natural gas displacement is based on the expected thermal output and utilization rates of projects, which varies by project capacity.

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Energy Benefits and Costs			
Change in Electricity Consumption (GWh)	-331	-876	-668
Change in Natural Gas Consumption (BBtu)	-1,413	-3,772	-2,871
Change in Biogas Consumption (BBtu)	3,598	9,522	7,261
Change in Renewable Energy Capacity (MW)	40	105	80
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	1,673,531	2,796,683	2,339,415
SO_2 Emission Reductions (MT)	197	193	272
NOx Emission Reductions (MT)	-778	-2,222	-1,629
Hg Emission Reductions (MT)[a]	NE	NE	NE
Economic Benefits and Costs			
Capital Expenditures ($ Million)[b]	$37.03	$0.24	$15.80
Maintenance and Repair Costs ($ Million)	$9.46	$20.47	$16.09
Fuel Savings ($ Million)	$44.78	$131.53	$96.61
Net Present Value ($)			$1,299,263,126
Cost-per-ton of GHG Emission Reductions ($/MTCO$_2$e)			-$17.54[c]

"NE" indicates that the value was not estimated.

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

[a] *Appropriate emission factors for Hg from biogas consumption were not readily available.*

[b] *Capital expenditures of $8.64 million for coal mine methane capture occur in 2020, 2024, and 2037. These years are not shown in this table, but are captured in the annual average capital expenditures.*

[c] *Negative cost-per-ton represents net cost savings.*

[81] Jones, David and Paul Lemar. 2015. Combined Heat and Power Market Potential for Opportunity Fuels. Resource Dynamics Corporation. Prepared for Oak Ridge National Laboratory. ORNL/TM-2015/745. Accessed July 3, 2018. Available at: https://info.ornl.gov/sites/publications/Files/Pub60457.pdf

Sector: Agriculture

Strategies include:

- Use agricultural best practices

Strategy: Use agricultural best practices

Actions include:

- Increase adoption rate of and provide training for no-till farming practices

Action: Increase adoption rate of and provide training for no-till farming practices

To quantify the cost and effects of this action, the analysis team used the following assumptions, data, and methods:

- Total Acres Planted: The analysis team assumes total acres planted in Pennsylvania will increase by approximately 2 percent annually based on the U.S. Department of Agriculture (USDA) Pennsylvania Tillage Survey statistics for 2013 and 2014.[82]
- Acres Planted by Crop: The team assumes that the percent of acres planted by crop will be consistent with the average percent of acres planted by crop from 2011 to 2017, as obtained from the USDA National Agricultural Statistics Service QuickStats database.[83]
- Tillage Adoption: The team assumes conventional tillage acres will transition to reduced tillage acres, and reduced tillage acres will transition to no-tillage acres.[84]
    - No-Till Adoption: According to USDA's Pennsylvania Tillage Survey statistics, no-till acres increased by approximately 8.5 percent from 2013 to 2014.[85] The analysis team conservatively assumes no-till acres in Pennsylvania will increase by approximately six percent annually based on the slower, historical trend of no-till adoption. The team also assumes that no-till adoption will reach a maximum of 98 percent of acres planted by 2024.
    - Reduced Till Adoption: According to USDA Pennsylvania Tillage Survey statistics, reduced till acres decreased by approximately 16 percent from 2013 to 2014. For this analysis, the team assumes this trend will continue through 2018. After 2018, reduced till acres will decrease by approximately 30,000 acres annually until no-till adoption

[82] https://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Annual_Statistical_Bulletin/2013_2014/ Accessed on July 4, 2018.
[83] https://quickstats.nass.usda.gov/ Accessed July 4, 2018.
[84] In 2013, conventional till acres comprised 16.6 percent, reduced till acres comprised 21.5 percent, and no till acres comprised 61.9 percent. USDA. 2015. Tillage Practices with Updated Alfalfa Seedings and Final Acreages. Accessed July 3, 2018/. Available online at: https://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Survey_Results/tillage%202014%20jan%2020125.pdf
[85] https://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Annual_Statistical_Bulletin/2013_2014/ Accessed on July 4, 2018.

reaches 98 percent of total acres planted in 2024. After 2024, the share of reduced till acres will remain constant at approximately one percent of total acres planted.

- Conventional Till: Conventional till acres are assumed to equal the difference between total acres planted, no-till acres, and reduced till acres.

- Carbon Sequestration: The analysis team obtains emission reductions by crop/tillage practice for USDA's Northeast region from the USDA's report *Greenhouse Gas Mitigation Options and Costs for Agricultural Land and Animal Production within the United States.*[86] The team then weights emission reductions by crop/tillage practice according to Pennsylvania's average share of acres planted by crop from 2011 to 2017.
- Changes in Yield: Similarly, the team obtains changes in yield by crop/tillage practice for USDA's Northeast region from USDA's report *Greenhouse Gas Mitigation Options and Costs for Agricultural Land and Animal Production within the United States.*[87] The team then weights changes in yield by crop/tillage practice according to Pennsylvania's average share of acres planted by crop from 2011 to 2017.
- Changes in Production and Revenue: To determine decreases in revenue due to reduced yield, the analysis team multiplies estimates of reduced yield by the projected estimates of conventional, reduced, and no-till acres in Pennsylvania to obtain reduced production. The team then multiplies production by weighted revenue in dollars per short ton of production.
- Energy Savings: The analysis team estimates fuel savings by applying USDA regional estimates of fuel consumption ($/acre) for various tillage practices to the projected estimates of conventional, reduced, and no-till acres in Pennsylvania. The team assumes diesel, natural gas, liquefied petroleum gas (LPG), motor gasoline, and kerosene represented 73, 23, 2, 3, and less than one percent of consumption on a BTU basis, respectively, based on consumption data for the Agriculture economic sector from U.S. EPA's 1990-2016 *Inventory of U.S. Greenhouse Gas Emissions and Sinks.*[88]
- Capital Expenditures: The analysis team relies on estimates of capital costs per acre from University of Illinois' 2017 Machinery Cost Estimates.[89] The team then applies per acre capital costs to the projected estimates of conventional, reduced, and no-till acres in Pennsylvania.
- Operation & Maintenance (O&M) Costs: The analysis team weights USDA Pennsylvania O&M plowing, planting, drilling, and spraying costs by crop, fertilizer usage, and tillage practice. The team then applies the weighted O&M costs per acre to the projected estimates of conventional, reduced, and no-till acres in Pennsylvania.

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[86] U.S. Department of Agriculture. (USDA). 2013. Greenhouse Gas Mitigation Options and Costs for Agricultural Land and Animal Production within the United States. Accessed July 4, 2018. Available at: https://www.usda.gov/oce/climate_change/mitigation_technologies/GHG_Mitigation_Options.pdf

[87] U.S. Department of Agriculture. (USDA). 2013. Greenhouse Gas Mitigation Options and Costs for Agricultural Land and Animal Production within the United States. Accessed July 4, 2018. Available at: https://www.usda.gov/oce/climate_change/mitigation_technologies/GHG_Mitigation_Options.pdf

[88] U.S. Environmental Protection Agency. (EPA). 2018. Inventory of U.S. Greenhouse Gas Emissions and Sinks (1990-2016). EPA 430-R-18-003. Accessed July 4, 2018. Available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2016

[89] https://farmdocdaily.illinois.edu/2017/06/machinery-cost-estimates-for-2017.html Accessed July 4, 2018.

Summary of Annual Energy, Environmental, and Economic Benefits and Costs

	2025	2050	Annual Average (2020 – 2050)
Energy Benefits and Costs			
Change in Distillate Fuel Oil Consumption (BBtu)[a]	-213	-336	-247
Change in Natural Gas Consumption (BBtu)	-68	-107	-79
Change in LPG Consumption (BBtu)	-5	-8	-6
Change in Kerosene Consumption (BBtu)	-0.1	-0.2	-0.1
Change in Motor Gasoline Consumption (BBtu)	-8	-12	-9
Environmental Benefits and Costs			
Total GHG Emission Reductions ($MTCO_2e$)	208,331	328,070	241,905
SO_2 Emission Reductions (MT)	-0.2	-0.3	-0.2
NOx Emission Reductions (MT)	-18	-27	-20
Hg Emission Reductions (MT)[b]	NE	NE	NE
Economic Benefits and Costs			
Capital Expenditures ($ Million)	$14.15	$22.28	$16.20
Maintenance and Repair Costs ($ Million)	-$12.01	-$18.92	$14.00
Fuel Savings ($ Million)	$6.13	$11.74	$7.92
Net Present Value ($)			$161,843,143
Cost-per-ton of GHG Emission Reductions ($/mt CO_2e)			-$21.50[c]

"NE" indicates that the value was not estimated.

Notes: Positive "changes" indicate increases from BAU values, whereas negative "changes" indicate reductions from BAU values. Positive "reductions" indicate reductions from BAU, whereas negative "reductions" indicate increases from BAU.

[a] The change in distillate fuel oil consumption likely contains a small amount of biodiesel.

[b] Appropriate emission factors for Hg from LPG and kerosene consumption were not readily available.

[c] Negative cost-per-ton represents net cost savings.

Appendix B. Comments from the Climate Change Advisory Committee

Mark C. Hammond
mhammond@landairwater.com
610.898.3854

March 29, 2019

VIA ELECTRONIC MAIL

Mr. Kerry Campbell
Environmental Program Manager
Energy Programs Office
Rachel Carson State Office Building
400 Market Street
Harrisburg, PA 17101-2301

Re: CCAC Member Comment for Inclusion in the 2019 Climate Change Action Plan

Dear Kerry:

Climate change is an important issue with far-reaching ramifications that requires action. I support the Department of Environmental Protection's (Department's) leadership on this issue, and I believe that the 2019 Climate Action Plan[1] (2019 Plan) provides a basis for further discussion and evaluation that could and should lead to action. I particularly appreciate the time, effort and focused attention given by the staff of the Department during this multi-year development process, as well as Mr. A. Stevens Krug, who chaired the Climate Change Advisory Committee (CCAC) during issuance of the 2015 Plan in August 2016 and throughout almost the entire development process of the 2019 Plan.

The 2019 Plan focuses primarily on very ambitious strategies that could drive significant emission reductions (i.e. what to do) as opposed to detailing how to design and implement those strategies (i.e. how to do it). The previous Plan was less ambitious in scope but included more developed implementation steps for consideration by decision-makers. In many ways, as discussed more fully herein, the 2019 Plan stands alone as a complete document, as opposed to being an update that builds upon previous Plans.

The Department has a legal obligation to document CCAC members' agreements and disagreements with the Plan. The Department has chosen to meet this obligation by providing each

[1] All references to the ICF, Embargoed Pennsylvania Climate Action Plan (Mar. 8, 2019) (unpublished plan, on file with the Pennsylvania Department of Environmental Protection) provided by the Department.

CCAC member an opportunity to submit a comment letter for unedited publication in the 2019 Plan. This letter is submitted pursuant to that opportunity.

Overall, I believe that the substance of the 2019 Plan generally comports with the requirements of the Pennsylvania Climate Change Act, but I note that this Plan was prepared using procedures and calculation methodologies that varied significantly from the three previous Plans. Similarly, the role of the CCAC was significantly different during development of this Plan as compared to the three previous Plans.

I offer no opinion as to whether the Department's change in use of the advisory committee will ultimately be seen as an improvement or not. But I believe it is important that these changes be highlighted to inform the reader as well as to place certain aspects of the report into context. In addition, while the bulk of the report is well done and informative, there are several areas where I note significant disagreement with specific elements of the 2019 Plan.

CCAC Role and Plan Structure—*Change in Procedures*

The 2019 Plan represents the fourth Plan issued by the Department pursuant to the Pennsylvania Climate Change Act (2009, 2013 and 2015). The central role of the CCAC during development of each of the three previous Plans was assistance in creation and evaluation of the "work plans" to reduce greenhouse gas (GHG) emissions. In this plan, "strategies" are the functional equivalent of work plans. While the CCAC's role relative to the work plans has varied slightly between the three previous plans, the role of the CCAC in preparation of the 2019 Plan was much different, including changes to identification, development, and the ultimate decision to recommend which strategies are included in this Plan.

In each of the three previous Plans, the CCAC had an active role in the development of each work plan, which are the "cost-effective strategies for reducing or offsetting GHG emissions" that the Department must evaluate under the Act, including the identification of "costs, benefits and cobenefits of GHG reduction strategies"[2]. ICF, a global consulting company, which is identified as the "supporting analysis team," displaced the CCAC from its primary role in advising the Department on "identifying strategies with adaptation benefits and strategies with emissions reduction benefits".[3] While I support the concept of allowing the Department to use outside

[2] Pennsylvania Climate Change Act, 71 P.S. § 1361.7(a)(2), (3) (2008).
[3] 2019 Plan, p. 38.

resources for evaluation purposes, care must be taken that the contractor does not usurp the Department's (and CCAC's advisory) role on policy development and selection. I further note that the Plan is ICF's work product and published under their name as authors[4].

Voting—*Change in Procedures*

Each work plan in each of the three previous Plans was subject to a roll call vote of the CCAC members. The complete voting record was published in each of the three previous plans. The CCAC was not asked to vote on any of the strategies included in the 2019 Plan, and it is therefore unclear as to how much support any specific strategy received from the CCAC collectively or any specific member. In terms of meeting its statutory obligation under Section 7(a)(4) of Act 70 of 2007 to memorialize areas of agreements and disagreement with the Plan by the CCAC members, publication of the voting record in earlier Plans helped the Department fulfill this requirement.

Data Analysis—*Disagreement with Plan*

In terms of the data analysis performed by ICF, it appears that much of it consisted of national data "scaled" to Pennsylvania and/or studies performed in other states but applied to Pennsylvania without recognition of state-specific factors. Despite repeated request by CCAC members and discussion at CCAC meetings with ICF representatives present, ICF did not incorporate Pennsylvania specific data already compiled by the Department and other Commonwealth agencies into its analysis or the 2019 Plan. Similarly, during discussions at CCAC meetings, ICF appeared unfamiliar with the contents of the three previous Plans and other information specific to Pennsylvania. Collectively, these issues/omissions reduce the efficacy of the 2019 Plan. Similarly, the strategies do not include the detailed implementation steps as in earlier Plans.

Combined Heat and Power (CHP)—*Disagreement with Plan*

Each of the three previous Plans evaluated GHG emission reductions from new CHP sources using "marginal" dispatch data and analysis. Marginal dispatch is the U.S. EPA recommended method for calculating emission reductions when calculating emission reductions from new sources

[4] 2019 Plan, cover page.

of electricity generation. The 2019 Plan explicitly discusses this fact, and directly cites to the U.S. EPA's guidance that states marginal dispatch should be used[5]. Marginal dispatch is noted as being the more accurate and preferred method as compared to the "average grid electricity emission factor," and the 2019 Plan includes a full explanation of this fact. However, with no explanation as to the basis for the decision, the Plan includes analysis using the average factor in lieu of the more meaningful and accurate Marginal factor.

This error was identified and discussed by the CCAC members at a CCAC meeting. In addition, individual CCAC members submitted written comments on this precise issue to the Department during the 2019 Plan's development.

This is a fatal flaw in the 2019 Plan's evaluation of CHP and my area of biggest disagreement with the 2019 Plan. The use of the incorrect methodology by ICF changes the 2030 and 2050 emission reductions from positive to negative. The Department implicitly recognizes that the ICF analysis is flawed through its inclusion of CHP as a recommended strategy. Rollout of CHP is an important GHG emission reduction strategy that is feasible and already happening in the real world. In fact, installation of 40 gigawatts of new CHP capacity by 2020 was recommended by President Obama in a 2012 Executive Order as being an important national goal in fighting climate change[6].

Social Cost of Carbon—*Disagreement with Plan*

For the first time, the 2019 Plan includes a "social cost of carbon." While the cost of carbon can be a powerful tool for making policy decisions about how much overall GHG reductions should occur when factoring in economics, the use and selection of the monetary cost feels misplaced in this report. First, the social cost of carbon does not change the cost effectiveness of any plan relative to any other plan, nor is the social cost of carbon used explicitly in any of the analyses[7]. In other words, the selected cost affects all plans equally, and would not change the ranking of cost-effectiveness amongst the plans. Secondly, and much more importantly, the selected cost is not adequately supported by documented analysis in the 2019 Plan.

[5] 2019 Plan, p. 72.
[6] The White House, Executive Order – Accelerating Investment in Industrial Energy Efficiency (Aug. 30, 2012) (https://obamawhitehouse.archives.gov/the-press-office/2012/08/30/executive-order-accelerating-investment-industrial-energy-efficiency).
[7] The use of the social cost of carbon appears limited to Figures 3 and 19.

The draft Technical Support Document (TSD) prepared by ICF and provided to the CCAC cited to a withdrawn U.S. EPA document discussing the social cost of carbon, without noting that the document was withdrawn and clearly marked as such. Under President Obama's administration, U.S. EPA used $36 per ton as the 2015 and $69 per ton as the 2050 social costs of carbon, as noted in the withdrawn reference. The current administration withdrew that social cost of carbon and replaced it with $12 per ton as the 2020 and $26 per ton as the 2050 social costs. The $95 per ton for 2050 figure used in the 2019 Plan is selected from the withdrawn document, albeit without attribution (see 2.5% discount rate, year 2050 at https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html). The selection used in the 2019 Plan was made using a different discount rate than used by U.S. EPA during either President Obama's administration or the current administration. While $95 per ton may be an appropriate number, it is clearly much higher than the current 2050 figure as well as the 2050 figure used during President Obama's administration ($69 per ton) and its selection has not been adequately explained or supported by ICF.

Conclusion

I believe the 2019 Plan meets the legal mandate set forth in Act 70, and that with the exceptions noted above, provides meaningful advice to the Governor and the legislature regarding opportunities for further investigation and development that would lead to meaningful GHG emission reductions within the Commonwealth.

Sincerely,

/s/ Mark C. Hammond

Mark C. Hammond

March 28, 2019

Kerry Campbell
Energy Programs Office
Department of Environmental Protection
400 Market Street
Harrisburg, PA 17101

Re: CCAC 2018 Climate Action Plan

Dear Mr. Campbell,

This is the third edition of the PA Climate Action Plan (CAP) that I have been involved with. Each edition has intentionally been approached differently in order to address issues as they change over time. This edition was purposely intended to take a different tack. Not only does the CAP include economically feasible and beneficial recommendations for our environment to *mitigate* greenhouse gases, it also discusses *adaptation* strategies for the benefit of the Commonwealth.

The Climate Action Plan (CAP) concentrates on the mitigation of greenhouse gases. Recently Governor Wolf set a goal of reducing emissions for Pennsylvania consistent with the recommendations of the CAP analysis. Comparable greenhouse gas reduction goals were analyzed from around the nation. A target was developed, so we can evaluate changes in emissions, consistent with the intentions of ACT 70 of 2008, to monitor and make recommendations for greenhouse gas reduction.

Adaptation to climate change has started to be included in the 2018 CAP to advise the Commonwealth about changes that can be considered for economic and risk management.

The process of developing the CAP has changed over the years as well. For this edition, DEP used a consultant to develop the CAP, as well as help the Energy Office with energy data. This gave a fresh look at the CAP and the members of the CCAC had only 4 meetings in 2018 instead of 6 (2 meetings were canceled by DEP) to advise and interact with the consultant, ICF. The resulting report has a new look and a new perspective.

I am pleased with the energy efficiency, sustainable transportation, and clean energy recommendations in the Climate Action Plan. The ideas presented are practical and achievable.

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Steve Krug
AIA, PE LEEDap, AEE Fellow
Principal, Architect

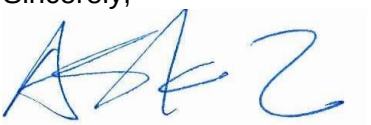
However, rather than just being a footnote in the report, I had hoped that the report would have included more narrative about the history and performance of cap and trade programs, such as REGGI. This information can provide more background and illustrate how Pennsylvania potentially could have and can benefit from participation. This applies to the Nuclear Power discussion as well. No doubt the cost of carbon will eventually be presented to Pennsylvania and the nation in the future. Honest and fair accounting for the cost of carbon will truly develop market-driven solutions.

One thing I hope we see more of in the future is a real discussion about *net-zero buildings* and *alternative fuel vehicles*. In order to achieve the goals set out in the CAP and Executive Order 2019-01, the Commonwealth will have to be designing and building many more net-zero buildings and alternative fuel infrastructure for vehicles. C-PACE financing and other helpful tools will encourage and promote the implementation of healthy high-performance net-zero buildings.

I want to thank the members of the Climate Change Advisory Committee for sharing their valuable knowledge and time. In particular, Rob Graff has offered great information about transportation, which is a major challenge; Mark Hammond for his expertise in recycling and waste management; Luke Brubaker for his enthusiasm for agriculture; Sara Nichols for incredible information about PA forests; Joe Sherrick for data and knowledge of Act 129 energy efficiency program for utilities; Patrick Henderson for his input about high efficiency natural gas technologies; Gary Merrit for his insights about electric utility generation; Marc Mondor for his support in energy efficiency for the built environment; and Terry Bossert for his valuable perspective on the practical aspects of the CCAC. Also, I want to thank AIA Pennsylvania and Krug Architects for their support of my involvement in the CCAC. The CCAC has made some impact over the years, as we have seen several legislative and executive actions. We have a long way to go.

Finally, I am looking forward to future discussions about *resiliency* and the economic benefits that Pennsylvania has to offer business by improving our infrastructure as we adapt to a changing climate.

Sincerely,



A. Stevens Krug, AIA, LEED™*ap,* PE, AEE Fellow
Principal, Architect
Krug Architects

March 29, 2019

Lindsay A. Byron, P.G.
Energy Programs Office
Department of Environmental Protection
400 Market Street
Harrisburg, PA 17101

(Via email: lbyron@pa.gov)

Re: Comments on the Department's Pennsylvania Climate Action Plan dated March 8, 2019

Dear Ms. Byron and Colleagues:

As a duly appointed member of the Climate Change Advisory Committee (CCAC), I offer the following comments on the Department's Climate Action Plan (CAP) based on the document provided to us dated March 8, 2019. The following comments are my personal views and do not represent the views of my law firm or any of its clients, or any other party. These comments are also in addition to joint comments submitted by several members of the CCAC and the two sets of comments should be viewed together as my comments regarding the CAP.

I believe it would have been beneficial and appropriate to have had the opportunity to discuss the Department's final Climate Action Plan (CAP) among the members of the CCAC at a meeting of the committee and to provide a committee response. Nevertheless, I appreciate the opportunity to provide comments regarding the CAP. It is obvious that Department personnel put a good deal of work into the CAP and produced a wide-ranging discussion of various options for addressing climate change. I also recognize that limitation of time and resources constrain what can be accomplished. Therefore, any comments suggesting that additional work should be done in a particular area should not be seen as a criticism but rather a suggestion for additional future analysis.

I am pleased to see a heavy emphasis on energy efficiency and conservation as I think the benefits that flow from those approaches are significant and multifaceted. I also appreciate the attention given to adaptation. The discussion of opportunities to reduce emissions in the waste management sector contains several excellent suggestions, such as the use of digesters and solar projects on closed landfill areas. Finding ways to recycle or beneficially use "waste" materials is a suggestion that could produce benefits beyond the reduction of greenhouse gas (GHG) emissions. To fully realize this potential, I would recommend that the Department examine its regulations and policies to remove some of the obstacles to greater beneficial use and recycling, particularly of industrial "wastes."

Generally, I do not favor setting GHG reduction goals since they are often just political gestures. However, in my view, the 2025 goal of a 26 percent reduction in emissions from 2005

levels is a reasonable goal that is achievable, although it will take some effort, and motivational and is an appropriate part of the CAP. I cannot say the same thing about the 2050 goal. One need only look at Figure 1 (p. 18) to see that the "Additional Reductions Needed" category far exceeds the assumed reductions achievable. While it may be appropriate for the Governor to set long-term aspirational goals in an executive order, repeating that long-term goal in a Climate Action Plan with no actions proposed that will come close to achieving that goal serves no purpose. The CAP will be revisited on three year intervals. Goals should be evaluated each time, being mindful of progress or lack thereof in the interim, and taking into account national and global achievements. Unless there is some reasonable plan for reaching the 2050 goal, it serves no purpose, other than to say that it matches the Paris Accord – a political gesture. Setting reasonably achievable shorter term goals with each iteration of the CAP will be of greater value to policymakers.

The CAP places very heavy emphasis on the energy sector but overlooks several important aspects of that sector. First, while noting that Pennsylvania is a top energy producing state resulting in great economic benefit, the CAP only mentions clean energy jobs as economic drivers. It fails to note the even larger economic driver from the fossil fuel industry. This missing context is important for policymakers to understand when reviewing a CAP that suggests significant curtailment of the fossil fuel industry. Secondly, the report seems to only begrudgingly mention natural gas and gives it only faint credit for the significant GHG reductions the Commonwealth has achieved, largely due to the increased use of natural gas for electric generation. These omissions and subsequent policy recommendations that would relegate natural gas to a minor role in electric generation reflect an anti-natural gas bias in the CAP. The Governor has often expressed his desire for the shale gas industry to prosper. The CAP appears to seek the opposite.

I am also puzzled by the decision to model only emissions related to energy consumed in Pennsylvania, when the report acknowledges that the Commonwealth is an electricity exporter. At page 31, the CAP states that the consumption-based model "allows emissions within Pennsylvania's borders to be fully captured." It is difficult to see how this is accurate if emissions from the production of exported electricity are ignored. More importantly, the consumption-based approach allows the CAP to ignore the importance of energy export to the Commonwealth's economy. Electricity is a product we produce and sell to others and any plan that works to diminish that product works to diminish our economy. Recommending programs such as an electric industry cap and trade program or joining the Regional Greenhouse Gas Initiative (RGGI) are only logical if one ignores electricity export as an important part of our economy. Successive administrations of both parties have recognized that RGGI is not right for Pennsylvania. When dealing with climate change, we are not dealing with PA's climate only – there is no bubble over the state. The emissions from the production of electricity that we export are, in fact, emissions that the exporting states do not have. That is not to say we should not continue to look for ways to decrease the emission; however, the CAP should have looked at the emissions related to exported electricity and analyzed the pros and cons on a regional basis.

I also question the proposal to subsidize the entire nuclear power industry based on the alleged economic woes of two plants. The fact is that TMI is operating only one reactor, which industry-wide has been known to be uneconomic, and other issues occasioned by its historic

problems impact its profitability. Other plants in Pennsylvania are profitable. Therefore, one wonders why the Department would promote a program that goes beyond helping just these two

allegedly unprofitable plants and propose a program that enriches the entire industry. For example, surely there could be some grant found to help TMI reopen the second reactor at a cost less that the negative $14 billion net present value (NPV) for this plan. Secondly, the plan assumes that if these two plants remain on line they will displace coal or natural gas fired generation, but there is no analysis to support that conclusion. They may simply meet growing demand and have no GHG benefit at all. Lastly, in addition to the significantly negative net present value calculation, the CAP does not account for the impact of increased electric prices for consumers. Again, this is an interesting policy position to take since the Governor has yet to express his opinion on the pending legislation.

Addressing emissions from transportation is vitally important, not only for GHG but also for criteria pollutants and air toxics. Accordingly, I commend the Department for addressing this sector. However, that part of the plan could use some additional detail and clarity. While significant GHG reductions are forecast from the growth in electric vehicle use, it appears that growth will be organic and independent of the CAP. It is not clear whether the steps recommended in the CAP will increase that growth. The technical support materials suggest significant reductions in gasoline and diesel fuel consumption will occur but also suggest a substantial increase in SO_2 emissions, without any explanation of what seems to be an inconsistency. In the interest of overall air quality moving to electric vehicles is essential, especially in urban areas. However, a negative $36 billion NPV and increasing SO_2 emissions causes one to question this action item as a viable GHG reduction tool. Perhaps a closer look at the broader benefits of the move to electric vehicles is warranted in the next CAP.

The only transportation related action plan that produces a positive NPV is the reduction in vehicle miles traveled (VMT) for single occupancy vehicles. However, there is no clearly defined plan set out to produce the desired result. General references to "incentives" and "penalties" do not demonstrate how it will be possible to pry Americans out of their cars. Compared to the detail put into programs to capture methane emissions from natural gas production, which produces a fraction on the MTCO2e emissions, the detail for addressing emissions in the transportation sector is lacking.

Lastly, it should be noted that neither the NPV nor the costs per ton of emission reductions presents the full picture of the economic cost of the recommendations. The CAP correctly notes, at numerous places, that a negative NPV is not the only metric to assess the economic effects of an action. The same is true for a positive NPV or a low cost per ton of reduction. The NPV and cost per ton of reduction are helpful metrics, but there are externalities that must be considered to appreciate the total economic and societal impact of an action when the time comes for policymakers to consider whether and how to implement the recommended actions.

Again, thank you for the opportunity to present my views on the Department's Climate Action Plan.

Terry R. Bossert

COMMENTS ON THE 2018 PENNSYLVANIA CLIMATE ACTION PLAN

Luke Brubaker, Member
Pennsylvania Climate Change Advisory Committee
March 29, 2019

I wish to offer the following comments on the Pennsylvania Climate Action Plan (CAP), prepared for the Pennsylvania Department of Environmental Protection (DEP) by ICF. I am a state board member of the Pennsylvania Farm Bureau (PFB), a general farm organization made up of more than 62,000 members. Since 1950, PFB has provided support, advocacy and informational and professional services for Pennsylvania agriculture and farm families. These comments are focused first on the sections of the CAP specifically related to agriculture, and then pivot to address the CAP in general. I also wish to make clear that these comments are to be treated as separate and distinct from any other comments to which I am a signatory that may be submitted to the Department on the CAP.

Comments on Agricultural Strategies in the CAP

First, several of the CAP's primary recommendations directly regarding agriculture—under the broad aegis of "using agricultural best practices" and "providing resources and technical assistance for farmers to adapt"—are generally in line with strategies that many Pennsylvania farmers are already utilizing. For example, providing financial incentives and support for agricultural best practices (if properly crafted to ensure meaningful compensation to farmers for planting crops or adopting farming practices that keep carbon in the soil or plant material) will build upon current successful conservation initiatives, such as the implementation of no-till farming practices.

At the same time, increasing the use and recovery of gas from agriculture will aid farmers engaged in more intensive farming operations to manage adverse environmental effects and legally meet the increased water and air quality standards imposed on more intensive agricultural practices, while also providing the opportunity to offset costs or generate revenue. Energy conservation and renewable energy generation technologies, such as digesters for methane capture and recovery; energy efficiency; and the production and use of renewable energy (e.g., biofuels, solar, wind) are current examples of integrated farm management strategies that are working for Pennsylvania farmers.

I would also comment specifically on Pennsylvania's agricultural community's utilization of solar energy systems. In Pennsylvania, solar energy systems are very often operated on more concentrated farming operations, and are developed and operated as an integral part of the farm's plan to meet the environmental standards imposed under state and federal law. At the same time, farmers must incur high input and operation costs to viably engage their farms in agricultural production, and development and maintenance of solar energy systems can require farmers to make significant capital outlays and incur debt.

Therefore, it is important to support the development of strategies that encourage the development of solar renewable energy credits (SRECs) with higher value. Doing so enhances the economic viability of projects that have already been developed; incentivizes future investment by farmers (and others) in additional Pennsylvania solar facilities; and expands farmers' options for compliance with ever-increasing environmental protection standards.

Finally, the CAP also makes positive recommendations in the area of supporting research and development to better assist farmers in handling weather events and better adapting to weather conditions, including establishing a network of agro-meteorological stations statewide to collect climate observations, including estimates of evapotranspiration, to support research and development of agricultural practices; expanding the collection and dissemination of local weather information for irrigation planning; improving the accuracy of existing real-time weather warning and forecasting systems for drought and extreme events; and developing and disseminating seasonal climate forecasts.

General Comments on the CAP

In responding to the issue of climate change, any law, regulation or policy implemented by the federal or Pennsylvania state government must adhere to a number of principles, which include, but are not limited to, the following:

- The action must be fair, affordable and achievable.
- The action must not make America (or Pennsylvania) less competitive in the global marketplace and put undue costs on American (or Pennsylvania) agriculture, business and consumers;
- The action must not be undertaken until other countries (or states) meet or exceed United States (or Pennsylvania) standards.

Unfortunately, the CAP, as currently constituted, fails to adhere to those principles.

First of all, despite the assertion early in the CAP that "Based on decades of research and evidence, it is commonly accepted that these events (higher temperatures, changes in precipitation, sea level rise, and more frequent extreme events and flooding) are highly likely a result of climate change caused by human activities and specifically emissions of greenhouse gases (GHGs)," a vigorous debate continues in the United States and throughout the world on exactly how the Earth's climate is changing, the likely current and future effects of the changes that have occurred and are occurring, and the role of human activity in whatever changes have taken and may yet take place. In short, much uncertainty exists regarding climate change and its effects, and any policy document purporting to address it should acknowledge as much.

Next, the greenhouse gas (GHG) emission reduction targets in the CAP were, according to its authors, used to gauge the results of a 26 percent reduction of net GHG emissions by 2025 and an 80 percent reduction of net GHG emissions by 2050, in order to keep global temperature increases below 2 degrees Celsius. These goals were also adopted by Gov. Tom Wolf in his January 2019 Executive Order (2019-01, "Commonwealth Leadership in Addressing Climate Change and Promoting Energy Conservation and Sustainable Governance"). However, given the current makeup of Pennsylvania's economy, numerous actions that the CAP recommends pertaining to some of the Commonwealth's most important industries (namely coal and natural gas generation) call into question its fairness, affordability and achievability, as well as its impact on Pennsylvania's future economic competitiveness.

This is important to the agricultural community not only in terms of operators' ability to afford fuel for their operations, but also because an increasing number of Pennsylvania farmers are finding it increasingly difficult to make a living, and a significant number of those would be out of business entirely if not for the natural gas drilling industry.

Because of the revenues farmers have obtained via natural gas drilling on their land, they have had the opportunity to buy equipment that they otherwise would not have been able to update. They have been able to install best management practices to improve the environment that they would not have otherwise been able to implement. And perhaps most importantly, younger members of farm families have been able to seriously consider staying home and continuing the family business, rather than leaving for job opportunities elsewhere. On many levels, agriculture has been improved because of the gas industry, and its future should be dictated by market forces.

But perhaps the most egregious flaw in the CAP is that its viability is entirely contingent on factors completely outside the control of the Commonwealth's policymakers. In arguing that Pennsylvania should have GHG reduction mandates or goals, the CAP states that the aforementioned targets are in line with those set by many other countries or states (citing the 2025 GHG target set by the 16-state "U. S. Climate Alliance" as a source of support for that assertion), and that "Aligning the targets within the 2018 CAP to targets set by other states helps to ensure that any target selected is achievable and that the corresponding GHG reduction strategies remain viable and cost effective."

Leaving aside the question of whether what another state's policymakers believe constitutes an "achievable" target or a "viable, cost-effective" GHG reduction strategy has any relevance to Pennsylvania's unique situation, the main problem with this line of argument is that even if all 16 states in the "U. S. Climate Alliance" met their 2025 emissions goals, that does not account for the actions of the other 34 states, not to mention those of other countries. This is important because the CAP includes the following heavily qualified statement on page 14:

> "If ***all*** states achieved similar GHG reduction targets, and other nations met ***comparable*** goals, climate science analysis suggests that global temperature rise ***could*** be kept below the 2-degree Celsius threshold cited by experts as the level beyond which dire consequences would occur..." (emphasis added)

In other words, the theoretical success of the CAP is totally dependent on ***every other state*** meeting the goals outlined in the plan (and some unspecified number of other countries meeting "comparable," but not necessarily the same, goals)—and even if that were to occur, there is apparently no guarantee that the forecasted rise in global temperatures will stay under 2 degrees Celsius. This hardly constitutes reasonable assurance that other countries or states will be meeting the standards outlined by Pennsylvania in the CAP—and it does not provide sufficient support for undertaking the actions contemplated therein.

In conclusion, I appreciate the opportunity to serve on the Climate Change Advisory Committee and stand ready to offer my perspective as the committee continues its work. Policies regarding climate change are among the most important and far-reaching actions Pennsylvanians will consider in the coming years, and there are common-sense actions that can be taken to benefit the environment and climate. ***Nevertheless, any action taken must not inflict real economic and social pain on the Commonwealth's citizens today in the name of creating a speculative, unverifiable vision of tomorrow built on a foundation of factors largely outside the control of state policymakers and voters***.

Delaware Valley Regional Planning Commission
190 North Independence Mall West
Philadelphia, PA 19106

March 29, 2019

Kerry Campbell
Environmental Program Manager
Energy Programs Office
Pennsylvania Department of Environmental Protection
Rachel Carson State Office Building
400 Market Street
Harrisburg, PA 17101

Dear Kerry:

I appreciate the opportunity afforded me as a member of the Climate Change Advisory Committee to provide comments on the *Pennsylvania Climate Action Plan* (Plan).

The Plan provides an ambitious, realistic, and balanced approach to reduce greenhouse gas (GHG) emissions in the Commonwealth. The approach taken to produce the Plan was sensible, focusing on those strategies that have the greatest potential for GHG reduction with preference for the most cost-effective policies. In addition, the Plan identifies key strategies for preparing the Commonwealth for the impacts of climate change that have already begun to manifest themselves, and are projected to increase

As acknowledged the Plan, even if fully implemented on schedule, it will only bring Commonwealth emissions slightly less than halfway to Governor Wolf's goal of reducing Commonwealth greenhouse gas emissions by 80% by 2050 from 2005 levels. This honest assessment acknowledges the scale of the challenge and the limitations of state policy alone. In addition to the state actions proposed, reaching Governor Wolf's goal will require sustained, concerted, and aggressive action at the household, firm, community, regional, national, and global level. It will also require continued technical advancement in energy efficiency and low carbon energy production. The plan is an important first step in navigating the narrow path between what is effective, what is economically feasible, and what will cause the least disruption to the way people like to live.

One key point: As the state transitions to an electric vehicle transportation system, it must find ways to replace the gasoline taxes that fund our transportation system.

With best regards,

Robert Graff
Manager, Office of Energy and Climate Change Initiatives
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rgraff@dvrpc.org

COMMENTS ON 2019 CLIMATE CHANGE ACTION PLAN
PREPARED BY PA DEPARTMENT OF ENVIRONMENTAL PROTECTION
PURSUANT TO ACT 70 OF 2008

SUBMITTED BY PATRICK HENDERSON

March 29, 2019

INTRODUCTION

As a member of the Climate Change Advisory Committee (CCAC), I appreciate the opportunity to share these comments and response to the final 2019 Climate Change Action Plan (Action Plan) of the Department of Environmental Protection (Department or DEP).

The Department staff and its contractor, ICF, are to be commended for their diligence in assisting the CCAC in reviewing prior drafts of this Action Plan, along with associated documents such as the Climate Impacts Assessment and Greenhouse Gas Inventory, and the facilitation of additional information to the CCAC during its development. The update to the Commonwealth's Comprehensive Energy Plan, which was first commissioned to assist in the development of Pennsylvania's first State Energy Plan in 2014, will be particularly valuable to policymakers charged with evaluating potential impacts to Pennsylvania's energy landscape.

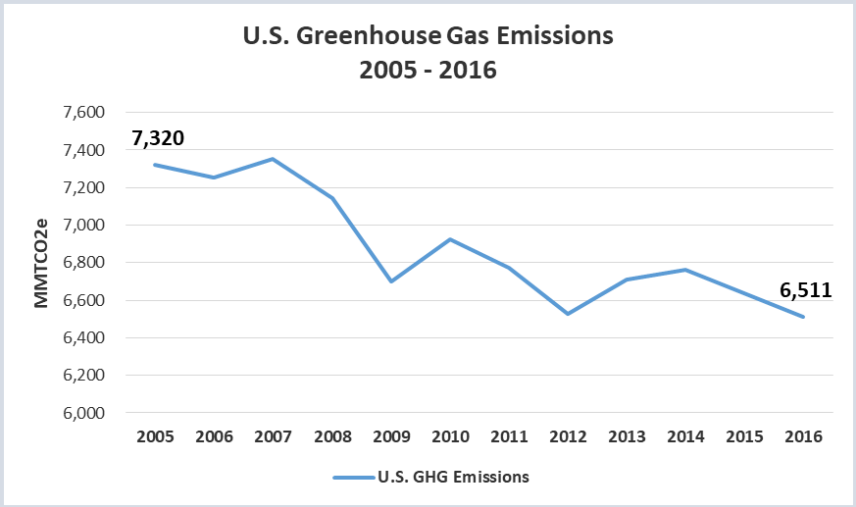
Despite this significant and commendable effort which went into preparing the Action Plan, there are several important areas where I diverge with the Action Plan's conclusions and recommendations. The following comments are offered in the spirit of helping to facilitate a robust conversation regarding the Action Plan by Department leadership, Pennsylvania policymakers and the public.

SPECIFIC COMMENTS

- **<u>Lack of Background Discussion on Recent Significant Greenhouse Gas Emission Reductions in Pennsylvania and the United States</u>**

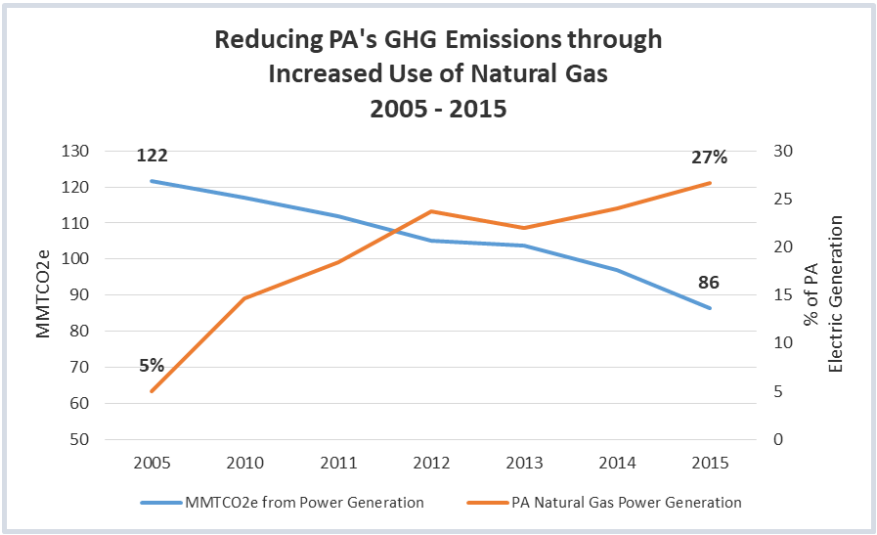
  The public, policymakers and media would have been well served by an introductory section to the report which described the history of greenhouse gas emissions during the Industrial Revolution to date; the economic and quality of life benefits delivered to society by access to affordable and abundant energy; historical fluctuations of both temperatures and climate (including naturally occurring fluctuations as well as those attributable to human activity); and a more recent snapshot that both acknowledges the need for additional progress, but also recognizes the significant progress that has been made in reducing greenhouse gas emissions. Unfortunately, despite explicit requests and recommendations for inclusion of this basic primer in the Action Plan, and readily available data, the Department chose to omit such an overview. This is a significant and baffling shortcoming of the Action Plan. That primer, therefore, is presented here.

The following chart illustrates that total greenhouse gas emissions in the United States, in carbon dioxide equivalent (CO2e),[1] have declined by 11.1% between 2005 and 2016:



Source: U.S. EPA – Inventory of U.S. Greenhouse Gas Emissions & Sinks: 1990-2016

Closer to home, the following chart illustrates that total greenhouse gas emissions from the electric power generation sector are down 30% since 2005 (through 2015). Moreover, there is a direct correlation between the increased use of natural gas in Pennsylvania's electric generation sector and this 30% decline, as abundant natural gas from the Marcellus, Utica and other unconventional formations provide a reliable, proximate and affordable fuel supply to new baseload power generation stations.



Source: PA Greenhouse Gas Inventory (Nov. 2018) & PA Draft Energy Assessment Report (April 2018)

[1] Carbon dioxide equivalent is a generally-accepted standard for expressing various greenhouse gas emissions in terms of the amount of carbon dioxide that would create the same amount of warming.

Without question, both Pennsylvania and the United States have seen historic reductions in greenhouse gas emissions, attributable to market-driven mechanisms that have delivered reductions in a manner that has shielded consumers from extreme price fluctuations or increases. In fact, consumers have experienced significant wholesale electricity price declines in Pennsylvania of over 40% over the past decade, translating to thousands of dollars of savings annually per household, and exponentially more for businesses and manufacturers.

- **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 imposition of a cap-and-trade scheme intended to lead to a phase-out of coal-fired generation after 2030, 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, would lead to a quantifiable emission reduction. However, the Action Plan fails to include tangible and specific benefits that Pennsylvanians will see should these recommendations be implemented, such as:

  - Less-than-projected average temperature increases
  - Less saltwater encroachment up the Delaware River estuary
  - 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 recognized in the Action Plan as necessary to avoid the most dire of consequences, it is imperative for the public and policymakers to understand the following: this benefit can

only be achieved if "*All states achieved similar greenhouse gas reduction targets, and other nations met comparable goals.*"[2]

- **PA DEP's Recommendations Do Not Meet PA DEP's Reduction Goals**

  Simply put, even if all fifteen quantified recommendations contained in the Action Plan are implemented, Pennsylvania does not come close to achieving the reduction goals stated in the Action Plan as necessary for Pennsylvania to do its part in achieving limits on global temperature increases. The chart below shows the associated goals and Action Plan shortcomings.

YEAR	ACTION PLAN GOAL*	ACTION PLAN (implemented)
2025	**26%**	**21%** (-5%)
2050	**80%**	**36%** (-44%)

* Compared to 2005 baseline

  Given the shortcomings demonstrated above, even if one accepts all the assumptions included in the Action Plan's recommendations it does not appear to be advisable – merely from an effectiveness viewpoint – to pursue the suite of recommendations contained within the Action Plan.

- **Inadequate Recommendations to Pacify the Extremists**

  In recent years, the public debate concerning climate change and global warming has moved aggressively toward the fringes of political discourse, leaving thoughtful dialogue, legitimate questions regarding scientific data and analysis, and vibrant discussion on what meaningful action ought to entail in the shadows.

  With this in mind, it is important to acknowledge that the suite of recommendations contained in this Action Plan will not remotely pacify many of the loudest voices demanding an immediate transition to a select number of energy resources. These voices claim legitimacy conferred by a growing number of elected officials, both at the federal and state level, who embrace nonsensical proposals such as the "New Green Deal"[3] and other similar initiatives that would, if adopted, massively increase consumer costs, exponentially expand poverty, reduce the quality of life of most if not all Americans, and relegate our economy into a perpetual national depression.

[2] Pennsylvania Climate Action Plan – Pg. 14

[3] Federal congressional resolution introduced by U.S. Senator Ed Markey (D-MA) & U.S. Representative Alexandria Ocasio-Cortez (D-NY) to eliminate economic activity which results in carbon emissions, including agriculture, air travel and other activities.

Despite efforts of the Action Plan to appease these constituencies by abandoning coal and marginalizing the benefits of natural gas, it still acknowledges other energy resources which have been disavowed by these extremists, including nuclear energy, hydropower, waste to energy and other alternative energy resources.

To be clear, the agenda of the anti-energy crowd is to kill not only the fossil fuel economy, starting with coal and progressing to natural gas, but also other resources that are part of our traditional, balanced energy portfolio. For example, consider the following from a recent message[4] delivered to elected officials in New York State and signed by over 600 self-proclaimed 'environmental' organizations:

> "*…any definition of renewable energy must also exclude all combustion-based power generation, nuclear, biomass energy, large scale hydro and waste-to-energy technologies.*"

This communication was signed by several prominent anti-energy, anti-jobs organizations active and based in Pennsylvania, including Berks Gas Truth, Delaware Riverkeeper Network, Food and Water Watch, Physicians for Social Responsibility – PA, Marcellus Outreach – Butler (PA) and others. These organizations claim that the steps they outline to elected officials, including the exclusion of the aforementioned energy resources, are required to achieve the 80% carbon emission reduction necessary to limit global temperature increases to less than 2° Celsius. Importantly, these are the same emission reduction and temperature goals identified by Governor Tom Wolf as part of the Climate Action Plan and the governor's Executive Order5 on climate change.

> *"And we're, like, the world is gonna end in twelve years if we don't address climate change…and your biggest issue is how are we gonna pay for it?"*
>
> **~ U.S. Rep. Alexandria Ocasio-Cortez (D-NY), #MLKNow 2019 Event – Jan. 21, 2019**

While nuclear energy, for example, is carbon-free from a direct emission standpoint (although it presents several challenging issues related to waste transport, treatment and disposal, national security threats, and results in significant carbon and other emissions during the extraction, processing and transport of its fuel source), in the view of these organizations maintaining the economic viability and market presence of nuclear energy impedes the transition to 100% baseload renewable energy.

In short, in their view utilization of these energy resources must be eliminated – regardless of the impracticability of doing so and without concern for the massive,

[4] Letter to New York General Assembly – "*Legislation to Address the Urgent Threat of Climate Change*" – January 10, 2019

[5] Executive Order 2019-01: Commonwealth Leadership in Addressing Climate Change and Promoting Energy Conservation and Sustainable Governance https://www.oa.pa.gov/Policies/eo/Documents/2019-01.pdf

unprecedented and detrimental impact on consumers, particularly low-income residents, or an economy that relies upon an abundant, diverse, reliable and affordable energy portfolio and an electric grid that pairs supply with demand. To presume that there is a pragmatic middle ground to be achieved with organizations such as these is naïve, and because their intentions are so well understood and stated, it is irresponsible to attempt to do so.

These implications go far beyond power generation, which is but one source of carbon emissions. According to an analysis[6] by Continental Economics, to achieve these goals it will be necessary to eliminate the cement industry (which releases carbon dioxide through the use of limestone), dairy and beef industries (as cows are significant methane polluters), prohibit the use of chemical fertilizers in agriculture and convert all transportation and manufacturing to electricity generated from renewable energy resources.

These implications are not practical, reasonable or necessary and ought not to be considered seriously by policymakers. Yet, they form the foundation of an approach under active consideration in Washington, D.C., along with several states, and mirror major concepts endorsed by some Pennsylvania organizations which have also embraced Governor Wolf's emission reduction goals in the Executive Order. In short, radical proposals are proffered by these organizations as necessary to achieve the carbon reduction goals of both the Action Plan and Executive Order and – because the challenge ahead is so urgent, extreme in its priority and noble in its pursuit – cost ought not to be a contemplation or consideration.

- **<u>Use of Dubious or Discredited Reports</u>**

  The proposed action entitled "Implementing policies and practices to reduce methane emissions across oil and natural gas systems"[7] relies, in part, on an Environmental Defense Fund Tool for Evaluating Options for Reducing Methane Emissions as part of its key analysis assumptions. Significant and unresolved concerns regarding the credibility of this report were shared with Department staff as part of the informal committee comment period, but were not addressed in the final Action Plan. These include:

  - The report conducted no new sampling or original data gathering;
  - The Environmental Defense Fund's (EDF) tool included no collaboration with the natural gas production industry; failure to do so not only excludes the recognized experts in the area, but also runs counter to

[6] *The Drive to Make New York 'Zero Carbon' is Insane*. Jonathan Lesser – Continental Economics & Manhattan Institute: https://nypost.com/2019/01/09/the-drive-to-make-new-york-zero-carbon-is-insane/?utm_campaign=iosapp&utm_source=mail_app – January 9, 2019

[7] Climate Change Action Plan – Pg. 80

accepted methods recommended by the National Academy of Sciences for study publication;

- The report contains an over (or exclusive) reliance on daytime measurements and observations, which leads to a so-called 'daytime bias' where activities that routinely occur during daylight hours, such as repairs or liquids unloading, are then extrapolated over 24 hours[8];

- The tool and its conclusions contradict EDF's own earlier studies, which concluded unconventional well site operations exhibited significantly lower leakage rates. EDF's report and the Department's utilization of it smacks of results-shopping.

- **<u>Attribution of Nearly Every Weather Event to Climate Change</u>**

  It is not always 70 degrees, mostly sunny, with a comfortable breeze outside. Yet there is a propensity to attribute most any weather event of significant impact as an effect of climate change – and more specifically, human-induced climate change.

  The Action Plan embraces this concept, and even goes so far as to include dire warnings of national and global decimation to justify the necessity for specific policy objectives within Pennsylvania. For example, readers are informed that extreme events have cost the United States more than $1.1 Trillion since 1980, 9 while on an international stage, five million people will die between 2030 and 2050 due to climate change. Additionally, $2-4 Billion in new direct costs will be borne annually. These numbers are offered without citation, and readers seemingly are to accept that all significant weather events are attributable to climate change.

  As importantly, no context is provided around these numbers, particularly the most egregious projection: human deaths. However, according to a comprehensive data analysis 10 by the Reason Foundation aggregate mortality attributable to extreme weather events since 1920 has declined by 90%. According to the analysis:

  - 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;

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[8] The National Academy of Sciences recently released a study critiquing variability in emission estimates from top-down/bottom-up analysis that may be instructive: https://www.pnas.org/content/115/46/11712

[9] Climate Change Action Plan – Pg. 13

[10] 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 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.

Previous assertions of impending doom, oftentimes offered as reflective of scientific consensus at the time, have been woefully and frankly embarrassingly inaccurate. Several are worth noting here to illustrate this point. Consider the following:

- **James Hansen**, director of the NASA Goddard Institute for Space Studies, top advisor to former President Barack Obama, and recipient of awards and recognition from the Heinz Family Foundation, PNC Bank, Time Magazine and other notable organizations, stated just ten years ago that by 2018, the Arctic would be ice-free in the summer, and that lower Manhattan would be submerged by five feet of water;

- **John Holdren**, a University of California physicist, claimed that climate change-induced famines could kill up to one billion people by 2020;

- **Paul Ehrlich**, a Stanford Professor and prominently-cited climate change commentator, warned in the 1970's that within twenty-five years, the United Kingdom would be largely inundated in water and overwhelmed by poverty and famine due to climate change.

None of this is to suggest that people ought to be willing to accept some level of damage, death or despair. Rather, it underscores the importance of context in how any data is reported. Assertions intended to alarm readers, rather than inform them, simply are not helpful to advancing informed and constructive dialogue on serious policy issues.

It should be acknowledged that humankind has made significant and unprecedented progress in the past one hundred years in a multitude of arenas – medical knowledge and basic health care; energy affordability; housing and building resilience; weather forecasting and many other aspects too numerous to delineate – that are unquestionably enhanced, and in many cases made possible only because of, access to and utilization of affordable energy resources, most prominently fossil fuels such as coal and natural gas.

CONCLUSION

Climate change has and will continue for some time to occupy a significant portion of the public policy discourse in our Commonwealth and nation. It should not, however, be contemplated in a vacuum. Other critical policies will, and ought to, occupy significant space in our ongoing

national conversation, including economic opportunity and prosperity, national security, education, access to affordable and world-class health care, to name just a few.

With respect to climate change and this Action Plan, it is immeasurably more difficult to prescribe and successfully achieve a path forward without a robust understanding and appreciation of our past and the complex realities which shaped our present station. I urge drafters of future Action Plans, as well as policymakers, to consider this important issue in that light.

STEPHEN McCARTER, MEMBER
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House of Representatives
COMMONWEALTH OF PENNSYLVANIA
HARRISBURG

COMMITTEES

AGING & OLDER ADULT SERVICES
APPROPRIATIONS
EDUCATION

March 29, 2019

Kerry Campbell
Environmental Program Manager
Department of Environmental Protection
Rachel Carson State Office Building
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Harrisburg, PA 17101

RE: 2018 CAP Commentary

Dear Kerry,

The impacts of climate change both in the United States and world-wide are now apparent for all to see. There is hardly a week or even a day that goes by that we are not made aware of the changes occurring across our planet, our nation and even our own neighborhoods. Extremes of weather have become our new normal—massive flooding, cyclones devastating cities out of season, the rise of sea levels pushing water into our coastal communities, along with scientific reports that provide proof that we are witnessing only the beginning of what has surely become mankind's greatest challenge.

Yet as we release our third updated climate action plan for Pennsylvania, it is important to note that we, the Climate Change Advisory Committee, have yet to fully comprehend the scale and immediate need for action. We have improved our goals and our suggested steps for administrative and legislative action, but we have still not responded in a way that reflects the realities and immediacy of the situation.

As a legislator, I am torn between 1) what is achievable in a state where fossil fuel production and use add enormous amounts of greenhouse gas emissions into our atmosphere, propelling the deadly spiral of climate change to a point where our only response can be adaptation and 2) a desire to see a concerted push for a greener planet with the whole-hearted embrace of renewable energy, setting the standard for our nation and the world.

The economic situation in Pennsylvania tests our abilities as leaders to balance our current needs against an uncertain path to combat the changes swirling around us. We are blessed with and cursed by the enormous wealth of fossil fuel products that lie buried in the sub strata of Pennsylvania's landscape. Abundant natural gas, oil and coal have provided many with well-paying jobs and incomes over the past century. Natural gas and oil will undoubtedly continue to heat our homes and provide electricity to power our businesses and transportation in the near future. And estimates of Pennsylvania's fossil fuel reserves suggest that if extracted, could continue to do so at current levels for another century or more. We are challenged to either

limit or eliminate our use of these resources or develop economically viable technologies that would permit their use without the destruction they will otherwise continue to reap upon our planet.

A robust plan to contain methane leakage and burn off needs to be adopted immediately. And we must ultimately craft a plan that maintains a robust economy, provides ample revenue for our state budget and gives every Pennsylvanian across our diverse state an opportunity for a productive and beneficial livelihood with family-sustaining income. Our challenge is to do this in an era of increasing transformation that is occurring whether we want it to or not.

We, the leaders of Pennsylvania—the DEP, other agencies and the Pennsylvania state legislature—must provide strategies, prioritize their implementation and offer incentives to make sure this transformation is accomplished as a benefit to our entire state. We must especially help areas of the state that will be more adversely impacted from the transition to renewables while protecting the general populous from possible rising energy costs during the transition. All this must be accomplished in the shortest possible time period to assure our productive role in meeting our emissions goals. A bill to achieve 100% renewable energy in Pennsylvania by 2050 has been introduced in the House. It needs to be discussed and considered.

This Climate Action Report itself contains many excellent and thoughtful recommendations that if implemented will go a long way to meeting our immediate emission reduction goals. However, the report is light on how we anticipate achieving our 80% emission goal by 2050. It will take a renewable revolution and the support of a broad segment of Pennsylvania residents to achieve that goal. Planning needs to be done now to establish the needed infrastructure to make the goal achievable and to educate Pennsylvanians on climate action needs. These plans must be incorporated into every element of legislative action beginning now. It will take bold action to assure that workers dependent on fossil fuel employment are given the means and reassurance needed to make the transition to new opportunities without substantial loss of family sustaining income.

Page 22 of the Executive Summary of the plan points to this necessity: “The year 2025 is rapidly approaching and actions with large GHG and economic benefits and relatively low cost and political barriers offer Pennsylvania the best short-term solutions. In parallel, initiating actions that may take more time and resources to implement and have more trade-offs to consider will help Pennsylvania maximize the potential impact of this plan.”

Creating a diverse portfolio of clean, utility-scale electricity generation presents the most important trade-offs to consider, because the strategy has an impact on almost every sector of the Pennsylvania economy, as well as residents, businesses and government. How to achieve this with the most benefit to Pennsylvania and the least cost to Pennsylvanians? We must start now, not 25 years from now, creating both buy-in and infrastructure to ensure that the path toward our 2050 goals exists and is cleared of obstacles by 2025.

Legislation to help develop a robust solar industry both at the distributive and grid level is needed to add 60,000 to 100,000 jobs with median wages of $20-$38 or more per hour in rural, urban and suburban areas. Areas of available land for grid-level solar projects need to be identified and prepared for development. Carve-outs for solar need to be at least 10% by 2030 and renewable credits limited to Pennsylvania-generated solar electricity. Other recommendations suggested in the Department of Environmental Protection’s *“Pennsylvania’s Solar Future Plan”* need to be carried out immediately.

We must also develop strategies to expand wind generation throughout the areas of the state best suited for economically viable development, and the commonwealth needs to utilize its available land to enhance this development. Expanded development beyond the southwestern and northeastern parts of Pennsylvania

need to be explored, including the state's game lands given the increasing climate change impacts and planning needed to achieve even greater renewable expansion in the years to come.

The issue of nuclear power in Pennsylvania is more difficult to assess. Nuclear energy currently accounts for 42% of Pennsylvania's electrical generation. It appears, however, that the industry faces economic challenges in the coming decade, and these challenges need to be evaluated carefully before a decision can be made to assist the industry.

Nuclear-generated electricity impacts numerous elements of the Pennsylvania economy. Detailed evaluation of the industry's financial needs will be needed to effectively craft legislation that balances the needs of consumers with those of the nuclear energy providers. Issues related to the potential loss of jobs, onsite radioactive waste storage and the long-term future of nuclear power generation also need to be assessed. However, it is hard to imagine electrical generation in Pennsylvania without a strong nuclear component during the next two decades.

It is clear that Pennsylvania is at a crossroads in 2019. National energy and climate change policy lacks direction. Our Pennsylvania renewable standards will shortly be up for reconsideration. The nuclear industry is threatening to shutter two of its nuclear-generating facilities in the near future without the promise of financial help. The gas industry is expanding its reach throughout the state, not only for greater distribution but also for product export out of Maryland and possibly Philadelphia in the near future. And Pennsylvania is now the only state in the Mid-Atlantic and Northeast that is not a member of the Regional Greenhouse Gas Initiative. Combating these complex issues without a coordinated national plan makes the task more daunting; acting together with our neighboring states would seem to be beneficial, given the complexity and urgency of the situation. We should also assess the viability of other plans for a cap and trade program.

The need to act increases with every passing hour.

We need to avail ourselves of every tool at our disposal to address climate change and its impacts. Regulation and legislation are excellent tools, but they're not the only ones. Creating and/or freeing up financing—such as the strategy, mentioned on page 44, of funding a green bank through new revenue streams such as implemented in Vermont—is at the very least, another possible tool and needs to be seriously considered.

We cannot wait for 2025 to plan for 2050. And we cannot rest on our CAP leadership laurels. The many worthy actions recommended in the CAP need to stay foremost in the minds of Pennsylvania's leaders and leading agencies in the days, weeks and years to come—an understanding reflected in the suggestion on page 49 of establishing a statewide Governor's Sustainability Council and/or interagency workgroup dedicated to the implementation of leadership actions listed in the CAP as well as action in department-level plans.

The fierce and immediate urgency of climate change requires a fierce, immediate and sustained response. The lives and livelihoods of our children and their children require it.

Sincerely,

Steve McCarter
State Representative
Pennsylvania's 154th Legislative District

Comments of CCAC members Gary Merritt and Jaret Gibbons

As members of the Climate Change Advisory Committee (CCAC), we appreciate the opportunity to participate in the committee meetings and provide feedback to the Pennsylvania Department of Environmental Protection (Department) on the 2018 Pennsylvania Climate Action Plan Update (Report). The Report 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 (Plan) issued in 2009. This is the third update of the Plan under the Pennsylvania Climate Change Act (Act 270 of 2008), which requires among other things that the Pennsylvania Department of Environmental Protection (DEP):

- Develop an inventory of greenhouse gases (GHG);
- Administer a Climate Change Advisory Committee (CCAC);
- Set up a voluntary registry of GHG emissions; and
- Prepare and update a Climate Change Action Plan. Revisions to the Action Plan are required every three years.

While the CCAC was regularly updated on the Report at regularly scheduled CCAC meetings and given the opportunity to provide input and comments on the Report, the committee did not take any formal position on the report or its content. The CCAC or its members did not directly participate in the drafting or conduct any vote on or endorsement of the final report. However, CCAC members could provide their own comments on the report, which we do here.

Lack of cost analysis

The Report is quite expansive and addresses a multitude of issues identified by the Department to which ICF has researched and responded. However, while identifying a variety of issues and attempting to look at sustainability, the DEP has taken proactive approaches on a variety of issues. In the process, it does not provide a cumulative analysis of the integrated costs of these recommendations on state, county, and municipal government or those costs upon individual citizens. In addition, the Report did not identify the economic impacts on business and industry. The report should have identified a total cost by summing the costs of each aspect or recommendation to consumers and to the taxpayer.

Overreliance on energy generation sector

The Report continues to place most of the reductions of CO2 either directly or indirectly on the existing electric generation fleet. However, the report fails to recognize the contributions that Pennsylvania electric generating units (EGUs) have already made to significantly reduce the industry's GHG footprint as was required by the Clean Power Plan.

Clean Power Plan: State at a Glance

Pennsylvania

Pennsylvania's Interim (2022-2029) and Final Goals (2030)

PENNSYLVANIA			
	CO2 Rate (lbs/Net MWh)	CO2 Emissions (short tons)	
2012 Historic	1,682	116,657,632	
2020 Projections (without CPP)	1,486	106,682,061	
	Rate-based Goal	Mass-based Goal (annual average CO2 emissions in short tons)	Mass Goal (Existing) & New Source Complement
Interim Period 2022-2029	1,258	99,330,827	100,588,162
Interim Step 1 Period 2022-2024	1,359	106,082,757	106,598,711
Interim Step 2 Period 2025-2027	1,232	97,204,723	98,945,311
Interim Step 3 Period 2028-2029	1,146	92,392,088	94,036,616
Final Goal 2030 and Beyond	1,095	89,822,308	90,931,637

***The above Table obtained from EPA Website on the Clean Power Plan**

DEP Secretary McDonnell in his letter of March 15, 2018, regarding the U.S. Environmental Protection Agency (EPA) proposed rule to "Repeal of Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units (82 Fed. Reg. 48035, October 16, 2017) addresses this question based on the following paragraph included in his comments:

> "The need for energy is one of the primary drivers of greenhouse gas (GHG) emissions, and Pennsylvania is the third largest emitter of carbon dioxide in the country. Nevertheless, Pennsylvania has made significant strides in the past few years to reduce GHG emissions. For instance, the 2014 carbon dioxide (CO2) emissions from existing Pennsylvania electric generating facilities intended to be regulated under the Clean Power Plan (CPP) were 106,967,641 tons. In 2015, those emissions decreased to 96,266,428 tons, and again in 2016 to 87,613,794 tons. Accounting for emissions from new sources, the 2016 total CO2 emissions were 89,467,892 tons. See enclosed spreadsheet. Pennsylvania's 2014 CPP goal is 89,822,308 tons. Thus, Pennsylvania has already exceeded its 2030 CPP goal through a combination of market-driven techniques; like fuel switching and renewable energy standards and is doing its

fair share to combat climate change. In Pennsylvania, the CPP has proven to be a cost-effective way to reduce carbon pollution without sacrificing electric grid reliability."

This is a critical point in what Pennsylvania has already accomplished to date in terms of GHG emissions. The reductions are primarily driven by regulations such at Cross State Air Pollution Rule (CSAPR), Mercury Air Toxic Standards (MATS), and the development of Marcellus and Utica shale leading to an abundant supply of below market priced natural gas.

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 seven plants. Of those plants, one is scheduled to retire by 2021 and one is switching from coal to gas over the next decade, leaving only five operating coal-fired plants. This will result in nearly 25 MMTCO2e annually not being emitted.

There were 15 coal refuse fired plants – 6 bituminous and 9 anthracite. Of these, two facilities have been permanently retired and a third is converting to natural gas later this year. Several others are have moved to seasonal operating or are considering closure. 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.

One can assume the bulk of the CO2 reductions in Pennsylvania, since 2005, have come primarily from coal-fired power plants being shut down. Further, the Clean Power plan represents a 26.84 MMTCO2e reduction from the electric utility industry from 2012 levels. This in essence has already occurred. Between 2012 and today, the 26.84 MMTCO2e that have been eliminated from the utility sector are primarily from the retirement of much of Pennsylvania's coal-fired generation fleet. With an aggressive schedule presented in the Report to eliminate another 42 million MMTCO2e by 2025, of which a small part came from the closure of coal fired plants between 2016 and 2018, this leaves the question as to how it will be achieved and the cost of achieving the reduction.

From an electric generation standpoint, the Report is proposing the following policy changes without looking at the economic impacts of the electric generating industry and resulting impacts on users:

- Create a diverse portfolio of clean, utility-scale electricity generation
- Increase Alternative Energy Portfolio Standard (AEPS) Tier 1 targets, and further increase in-state generation and use of renewables
- Implement policy to maintain nuclear generation at current levels
- Limit carbon emissions through an electricity sector cap and trade program"

What is playing out with these initiatives is a "de-facto" reregulation of Pennsylvania's electric industry. While the Public Utility Commission (PUC) is not involved in the wholesale electric market, it is in fact responsible for approving the increases in utility rates paid by the consumer. Additionally, the approval of the pricing for AEPS credits is a PUC obligation. These types of out of market changes impact the PJM energy market and how generators bid and price capacity in the electric generating market. If these suggested changes are made to the AEPS, upwards of two thirds of generating capacity in Pennsylvania will be receiving subsidies from the state. This does not account for federal subsidies for wind and solar generation and any future federal subsidy for other types of generation.

Presently, the AEPS only provides valuable credits to Tier I generation as Tier II facilities obtain about a dime per Tier II AEPS credit. The AEPS was designed to encourage development of these projects in Pennsylvania, keeping the money in Pennsylvania. However, this not the case. Almost three-quarters of Tier I AEPS energy is being purchased from electric generating units in other states in the PJM market. In some cases, these states do not allow the purchase of similar credits from other states, including Pennsylvania.

From a competitive electric generating market perspective, the impact of these policies create a double hit for coal and natural gas EGUs when competing with solar, wind, and nuclear generation. First, these generation sources would obtain significant subsidies from both the AEPS and federal tax credits for solar and wind. Whereas, the coal and gas EGUs would be further burdened as a result of the cap and trade system charging for carbon emissions.

The Report also fails to take into account the cost of managing both low- and high-level radioactive waste from nuclear power plants. Further, as these plants age, the cost of maintenance increases, which include the management or replaces equipment. The solar industry has its own issues forthcoming dealing with the management of solar panels as they come to their end-of-life performance or even when there are panels being replaced in the interim for poor performance. This is not being considered as part of the costs today.

Coal refuse fired EGUs represent a major force in the reclamation of abandon mine land. The Report claims to protect these facilities by stating that the "post-2030 emission cap that is modeled leads to a phase out of most remaining higher carbon emitting sources of generation other than waste coal by 2050." However, by including a cap and trade program and subsidies for competing generation sources, the result will be the loss of nearly all of this environmentally beneficial power generation from the coal refuse fired EGUs. 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. Additionally, by precluding and extinguishing abandoned coal refuse pile fires created by spontaneous combustion or human interface, these facilities prevent uncontrolled emissions which contain significantly higher GHG and other emissions.

It needs to be recognized that the unreclaimed coal refuse sites are major source of water pollution from sediment laden runoff and mine drainage. In the 2013 Pennsylvania Climate Assessment Update, Penn State University was projecting wetter periods with increased runoff. From a climate change perspective, if, as projected, there are increased in more intense precipitation events, that will mean more silt and water pollution will come from these sites. For the unreclaimed abandoned coal refuse sites, this would mean higher sediment laden runoff and increase in mine drainage from these sites. Yet, while the Department discusses in overview form the need for stormwater management, it ignores the benefits of coal refuse fired units, thereby moving to a future without the tools available to reclaim and ameliorate water quality from abandoned mine lands polluted with coal refuse.

Stormwater Management and Water Resources

The projections of increased precipitation of higher intensity storms at different times of the year would result in increased stormwater flows to manage. The Report recommends that DEP's Stormwater Best Management Practices Manual as a "standard" operating procedure suggesting that it is a regulatory design.

If anything, the whole issue of stormwater management needs to be addressed. The Department's manual needs to be reviewed and updated to address future sustainability; and significant changes in design standards to address climate change may result in problems dealing with cities and local governments who had implemented storm water management controls and have initiated funding of these controls at the local level. They may be limited as to what they can actually implement in the future.

Further, the Report is more of a reflection of the Office of Policy and CCAC discussions. Based on the Penn State University Sustainability Report, the Department should have engaged its Water Resources Advisory Committee (WRAC) and reengaged and established it Statewide Water Resources Committee, which was established by the Water Resources Planning Act, signed into law on December 16, 2002, established a Statewide Water Resources Committee (SWRC) and six Regional Water Resources Committees that are charged with guiding DEP through the development of a new State Water Plan and updating it at five year intervals.

This SWRC Committee was responsible for insuring adequate water supplies and determining critical water planning area as well as:

- An Assessment of Floodplain and Stormwater Management Problems
- Water Supply Alternatives and Assessments
- Critical Water Planning Areas
- Drinking Water and Wastewater Sustainable Infrastructure

The Climate Change Sustainability document suggests that there will be different hydrologic impacts. If the Department truly believes that, then why hasn't it reconstituted the SWRC per the Water Resources Planning Act and begin to obtain their inputs on climate change and sustainability of our water and water supplies.

Recycling

The Report discusses recycling. However, it is basing much of its position on 2013 and earlier reports. Today, the recycling of paper, metals, and plastics are down. The markets have dried up. This can be seen by a recent article entitled: "Moment of reckoning:' U.S. cities burn recyclables after China bans imports" which indicates that:

> "The conscientious citizens of Philadelphia continue to put their pizza boxes, plastic bottles, yogurt containers, and other items into recycling bins. But in the past three months, half of these recyclables have been loaded onto trucks, taken to a hulking incineration facility, and burned, according to the city's government. It's a situation being replicated across the U.S. as cities struggle to adapt to a recent ban by China on the import of items intended for reuse."

China was a major buyer of used plastics and paper. However, the large percentage of these materials where not recyclable and thus went to their landfills for disposal.

Today, without markets for the recyclable materials, they build up in warehouses and are eventually shipped to incinerators or landfills for disposal.

Two points to be considered are:

1. Finding markets for the raw recyclable materials and create market incentives to use recyclable materials.
2. Taking steps that the material sent to a recycler is recyclable. Presently 35 to 40% of the material collected is nor recyclable for a variety of reasons. One issue is cross contamination resulting from mixed recycling materials that are not properly sorted and processed.
    a. For example, one new plastics recycling plant failed, because the bundle plastics if was purchasing to process was producing between 35 and 40% waste material that could not be recycled. Some of that was plastics that were not recyclable.
    b. In the reprocessing facilities are having hard times separating, maybe one should look at alternate week pickups (one for Plastic, metal and glass; and the other for paper and cardboard.

The value of recycling plastics has also diminished a result of increased shale gas development. Particularly, the large amounts of wet gas that contain natural gas liquids used as a feedstock for many plastic compounds can be produced cheaper thereby lowering the cost and impacting recycling.

Mr. Kerry Campbell
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March 31, 2019

RE: 2018 Pennsylvania Climate Action Plan Comments

Dear Mr. Campbell,

Thank you for the opportunity to provide comment to the 2018 Pennsylvania Climate Action Plan. I would like to thank PA State Senator Jay Costa (D - Forest Hills) for my appointment to this important role, and to acknowledge Stevens Krug for his steady leadership as Chair of the Climate Change Advisory Committee (CCAC), my reliable Alternate Joe Morinville, and the rest of my colleagues on the CCAC. I appreciate the opportunity and confidence placed in me for my participation in the Climate Action Plan process over the last four years. I would also like to thank my firm evolveEA, and AIA Pennsylvania, for their support of my service.

The Pennsylvania Climate Action Plan carries weight as an objective evaluation and as an instrumental document. The 2018 Climate Action Plan includes an exhaustive tally of the sources of carbon in the Commonwealth and, for the first time, addresses adaptability measures to address climactic forces already in progress. The Plan is unique in its scope, in the intensity of its evaluation, in the productive back and forth among the selected stakeholders, and its specificity to the uniqueness of our Commonwealth of Pennsylvania.

We are pleased with the results of the 2018 Pennsylvania Climate Action Plan and would like to use our perspective to provide the following comments for constructive consideration.

Governor Wolf has established important carbon reduction goals. With Executive Order 2019-01 *Commonwealth Leadership in Addressing Climate Change and Promoting Energy Conservation and Sustainable Governance* signed into law by Pennsylvania Governor Tom Wolf in January 2019, the Commonwealth has effectively established carbon reduction goals. These goals, linked to the baseline year of 2005, call for a reduction of 26 percent by 2025 and the more common reduction goal of 80 percent by 2050. Many of us on the CCAC have advocated for the importance of specific carbon goals within the Climate Action Plan, as goals are essential to the implementation of any plan. This addition is a key component to making this plan an instrument, rather than a mere position statement.

Health benefits of carbon reduction should be accounted. As a society, our way of thinking leads us to evaluate strategies as a function of financial returns. This Climate Action Plan goes a critical step further in also accounting for environmental benefits as well. While progressive and valid, Triple Bottom Line

accounting also accounts for health benefits. Less carbon emissions typically means cleaner air, more physical activity and less illness, all of which have great, measurable social returns and create more well-being for citizens of the Commonwealth.

Plan metrics are absolute. The 2018 Pennsylvania Greenhouse Gas Inventory carries a tally of consumption by the Commonwealth dating back to 1990 in five-year increments until 2010, then in annual increments until 2015, the last full year of complete and verified data. The metrics (e.g. BBtu, MMTCO2, and TWh) show the amount of energy sourced and used in absolute numbers. There would be value in having this data in a per-capita metric as well, as the population of Pennsylvania has increased by over 7.5% since 1990 but not uniformly between cities and rural areas. Additionally, as manufacturing has decreased, coal production has decreased, gas extraction has increased and technology has made workers more efficient; all of these factors could be reflected in per-capita metrics.

A price on carbon should be established and maintained. We can all emit for free, paying money for the fuel, but not for the sink. Carbon emissions have a cost that should be acknowledged. The US EPA has established this cost at $36 per ton in the Obama administration. The EPA does not currently acknowledge this cost, but a few states, such as Minnesota, recognize it. Using the market forces that drive our economy, those who economize emissions should be rewarded, while the actions of the profligate should be reflected by a financial cost.

Fracking has been a carbon reduction silver bullet, but all costs are not fully accounted. The advent of hydraulic fracturing over the last two decades, notably in the Marcellus Shale formation, has yielded a gas extraction revolution. This has had the double positive effect of creating scalable technologies and jobs, and that has lessened overall emissions due to the direct displacement of coal production. However, the immediate and long term ground-level and water-table impacts of fracking are not mentioned in this report due to a lack of consensus and long term study.

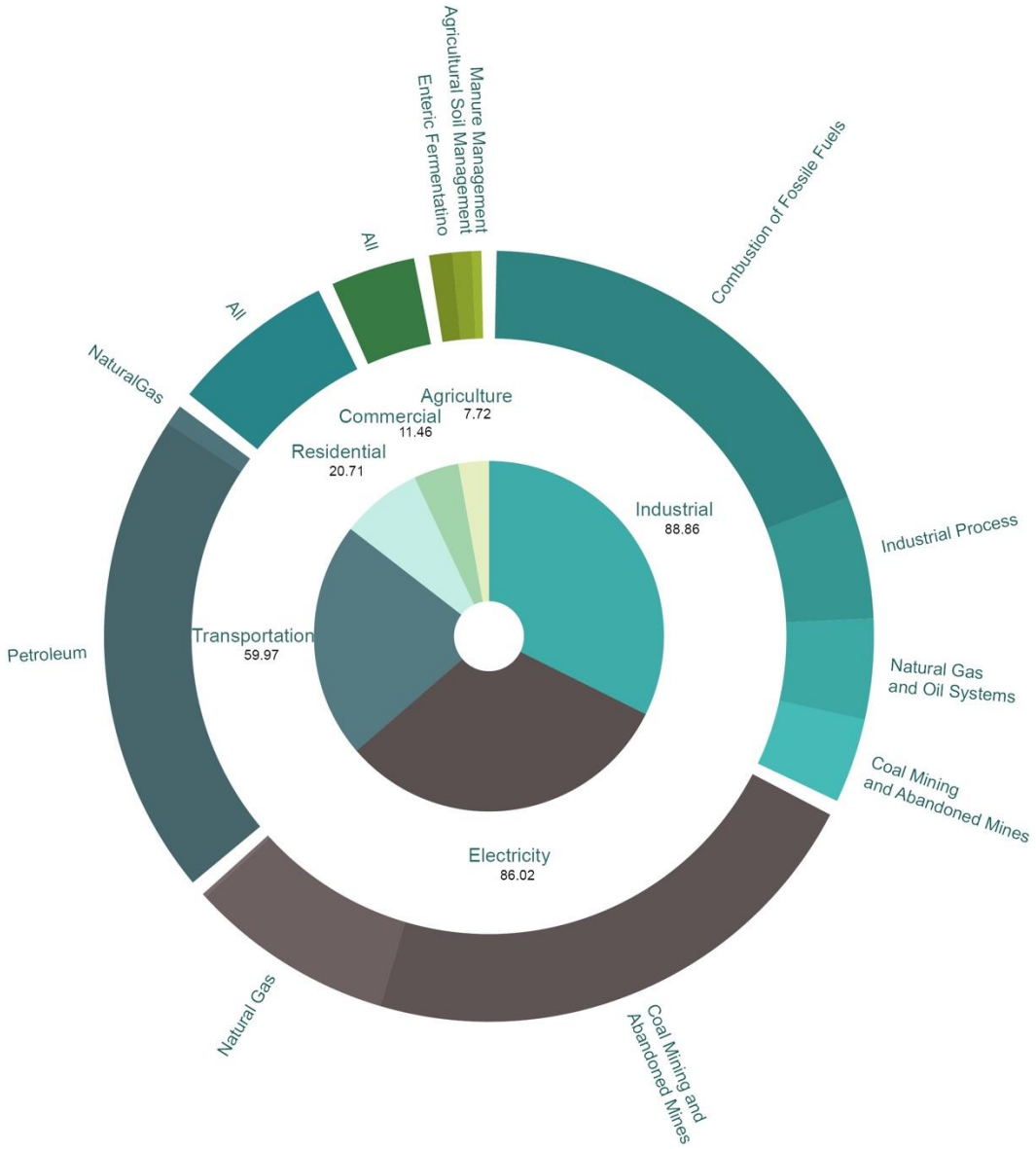
Nuclear power has long been a bane of environmentalists, but now, not as much. The Climate Action Plan calls for nuclear production levels to remain constant over the next decades in spite of the likely decommissioning of Three Mile Island in 2019 and Beaver Valley nuclear power plants, in 2019 and in 2021, respectively. Like coal, nuclear power is effectively being displaced by abundant natural gas, lest a nuclear bailout bill be forthcoming. The net effect will be that a no-carbon emission generation method will be replaced by one that does create emissions. Nuclear power has always been unpopular among environmentalists, but in light of carbon reduction goals specific to the scope of this Plan, this potent carbon-free electrical generation is now appealing, if not desirable.

Buildings and built form influence carbon in many ways. Commercial and residential buildings account for approximately 40 percent of emissions nationally, but only about 18 percent in Pennsylvania. However, building efficiency due to improved building codes (Act 36 of 2017), improved construction technology, increased adoption of building performance rating systems, and reduced costs for building-mounted photovoltaics allow buildings to be more energy efficient while also improving occupant health. Building energy efficiency, healthy interiors and on-site energy generation make buildings high-performing investments. The transportation associated with access to buildings is markedly less for denser patterns of development, with mass transit and walkability providing carbon reduction and health benefits.

Lastly, as a supplement to the data in the **2018 Pennsylvania Greenhouse Gas Inventory**, we would like to provide **graphic representations** of the data for your use.

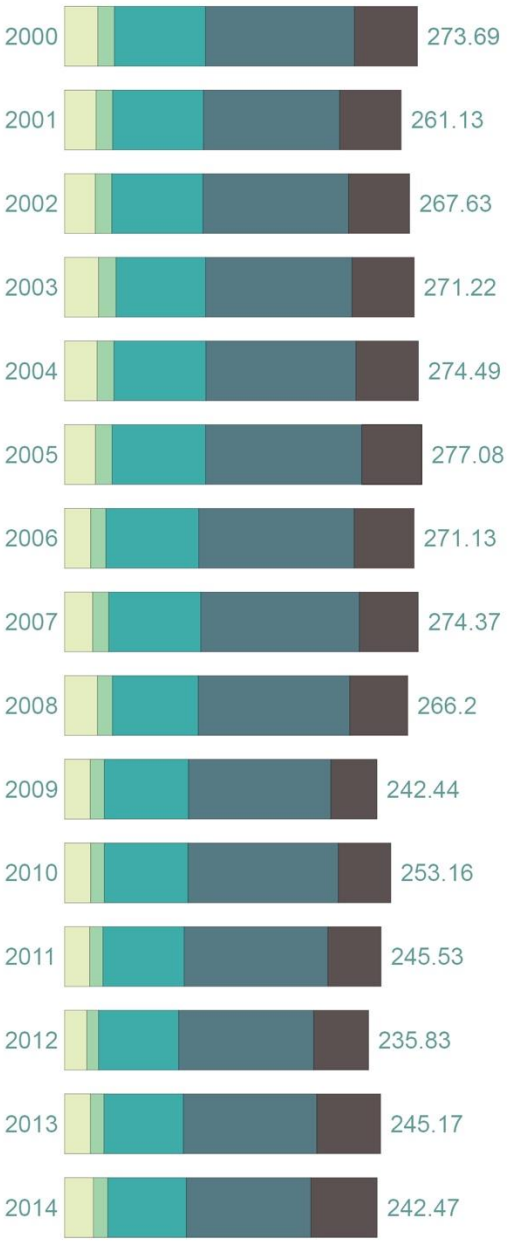
Green House Gas Emissions Breakdown

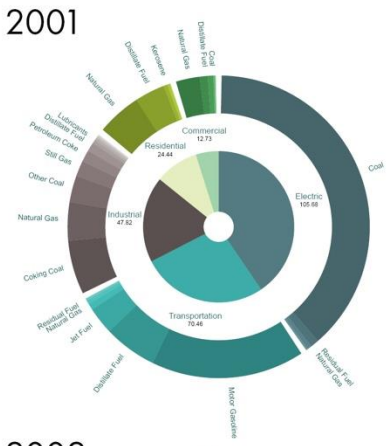
Pennsylvania 2015

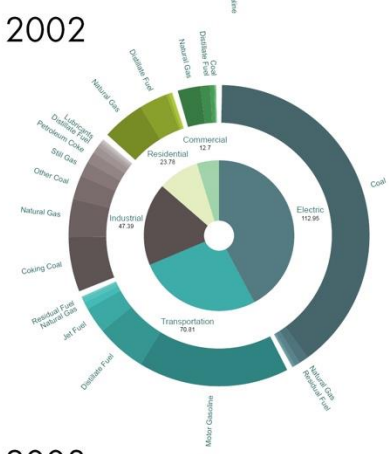


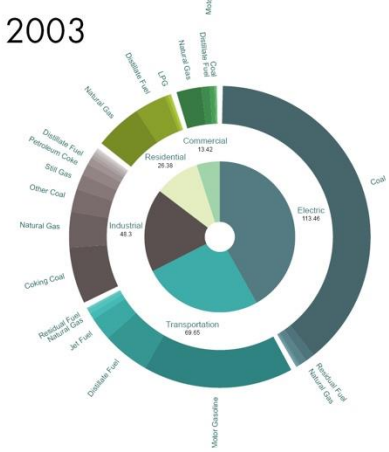
Green House Gas Emissions Breakdown

Pennsylvania 2001 to 2014









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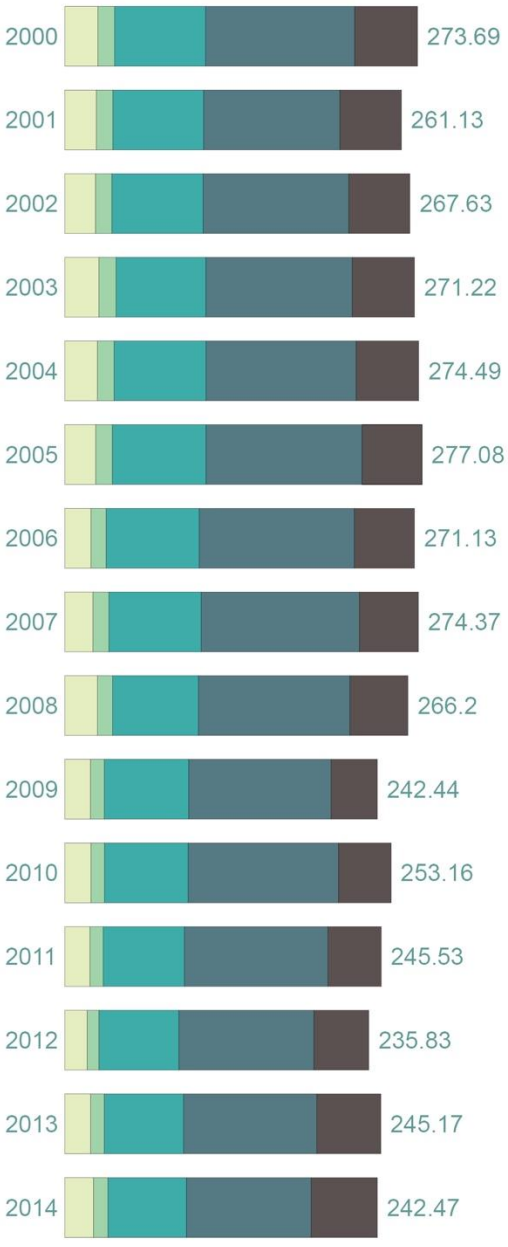
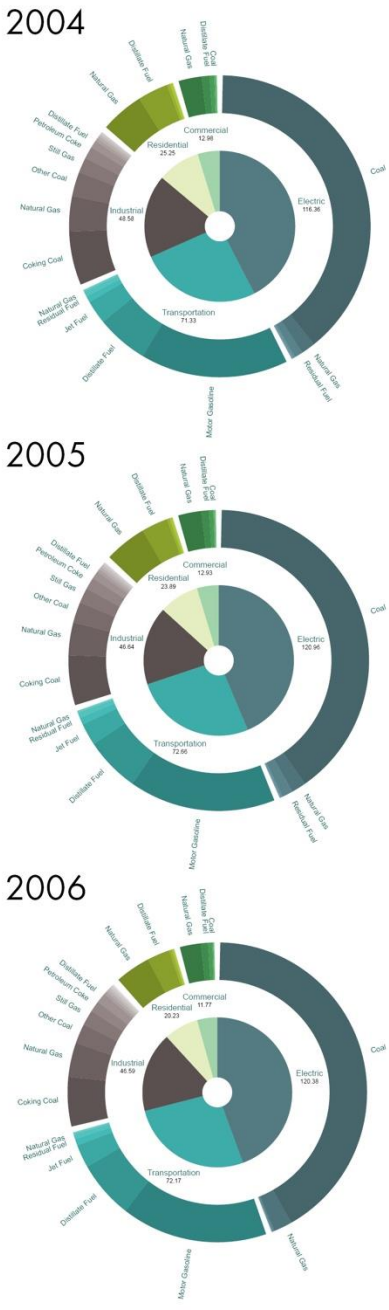
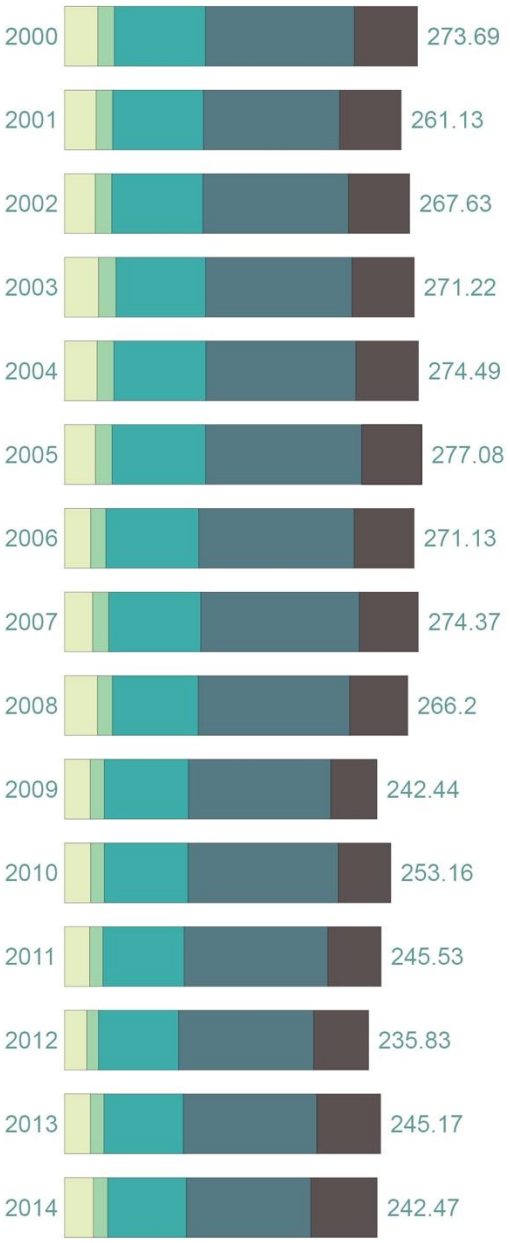
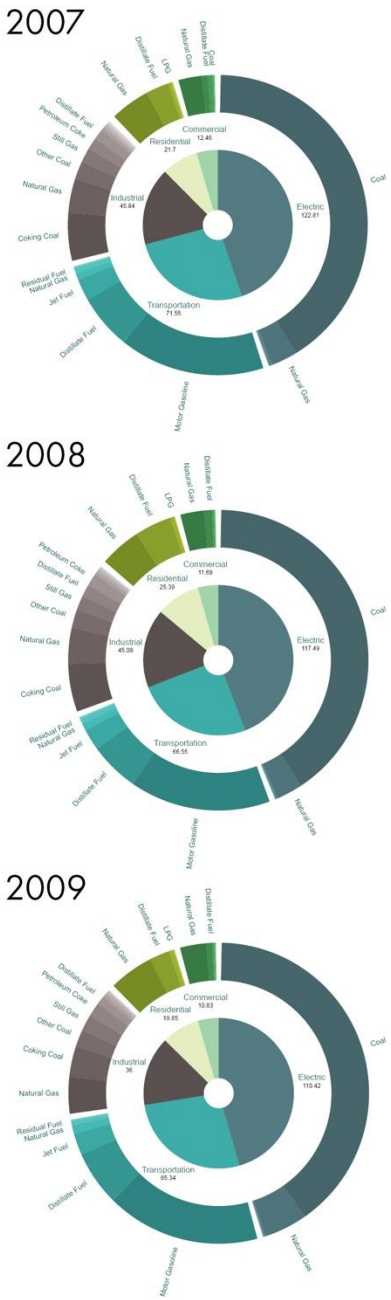




Green House Gas Emissions Breakdown

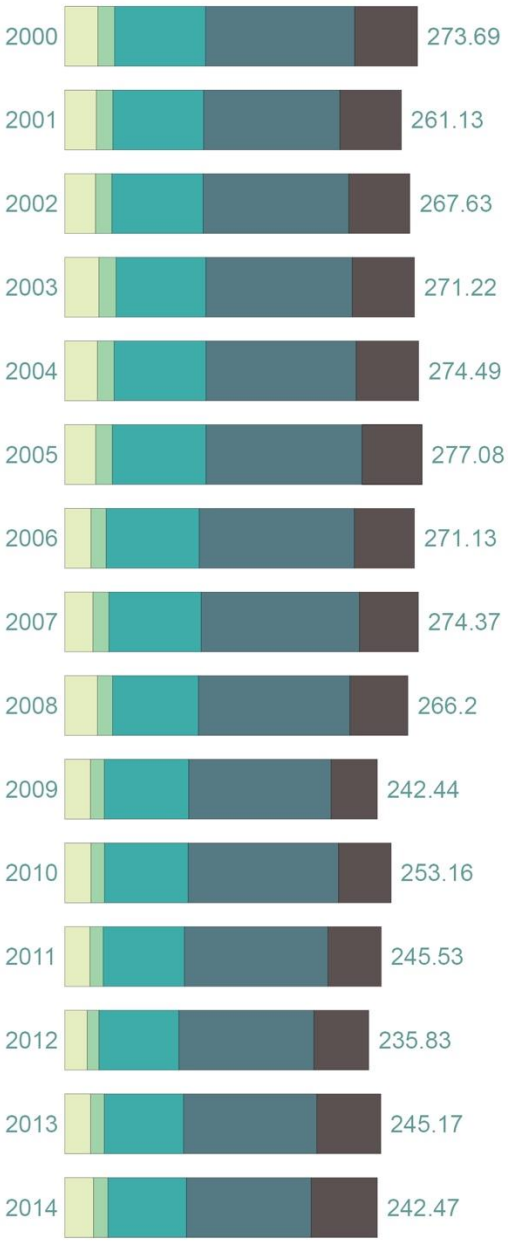
Pennsylvania 2001 to 2014

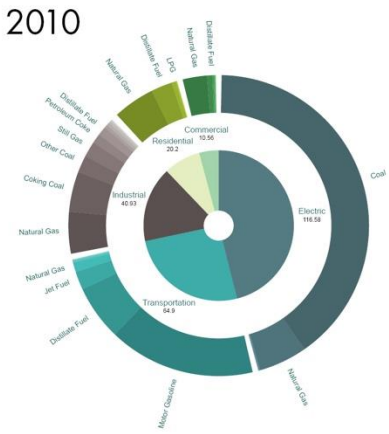


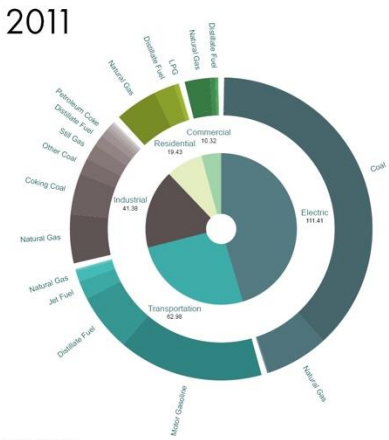


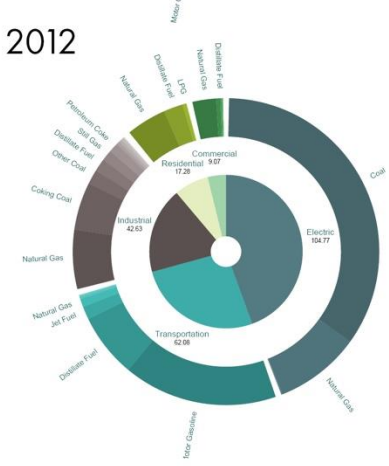
Green House Gas Emissions Breakdown

Pennsylvania 2001 to 2014









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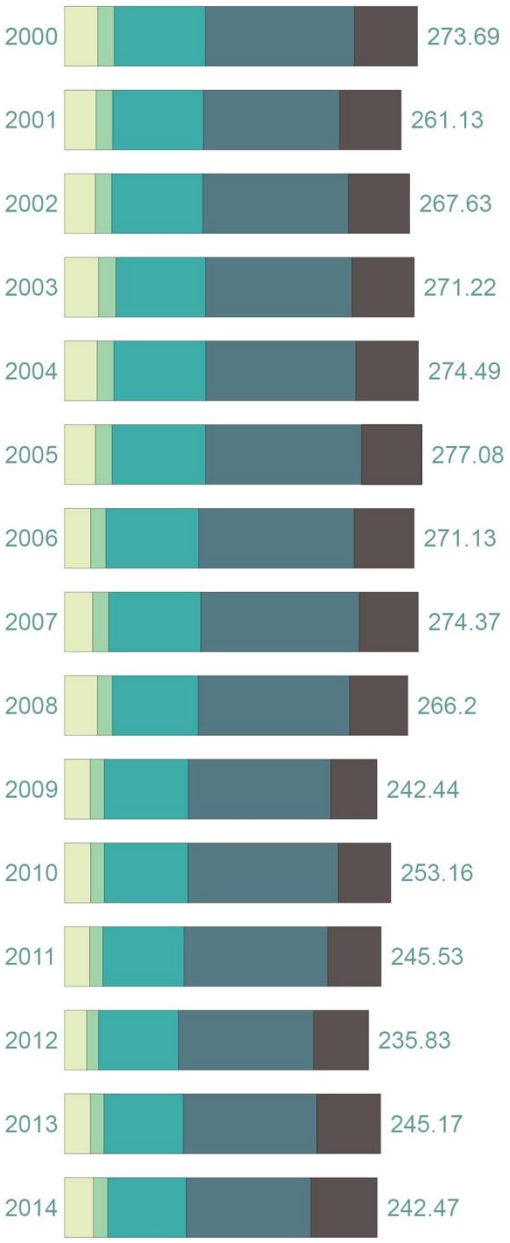
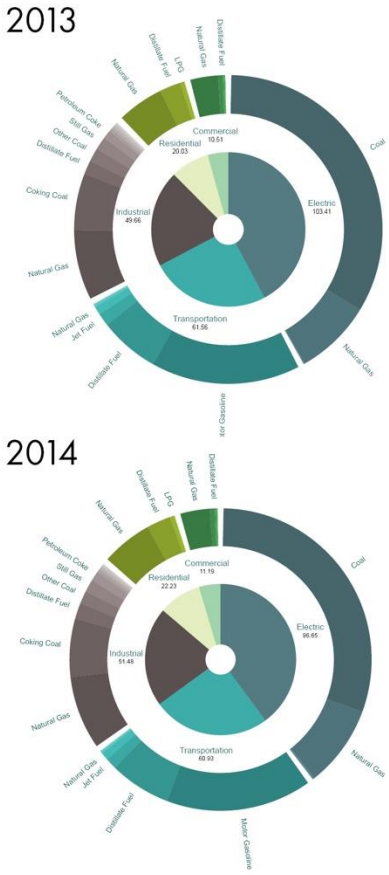
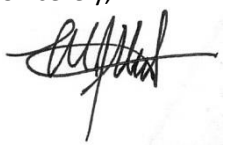




The graphics show 2015 data, the last full year for which complete data is available. Also shown is data from 2001 to 2014, year by year, in relation to bar graphs showing the year-by-year components and variations. We have these as raw files and are pleased to share if usable to you.

Sincerely,



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March 29, 2019

Introduction

As members of the Climate Change Advisory Committee (CCAC), we appreciate the opportunity to submit comments on the Climate Action Plan (Action Plan). We thank the staff of the Department of Environmental Protection (Department) and ICF for their diligence in preparing this Action Plan, and their responsiveness throughout the process of reviewing the Department's prior drafts of the Action Plan.

The CCAC represents many diverse viewpoints and has drawn upon the collective experience and expertise of its members to offer the Department and ICF input. While the CCAC has had opportunity to provide comments, it is important for policymakers and readers of this Action Plan to understand that the Action Plan is a policy document of the Department. It has not been prepared, nor approved – either formally or informally – by the CCAC.

Several members of the CCAC will be submitting more detailed comments regarding the final Action Plan. We appreciate the opportunity to have these comments attached to the final Action Plan. Additionally, the undersigned join together in offering the following comments which address several key, overarching concepts embodied in the Action Plan.

Foundation on Current State of Emissions in Pennsylvania

Despite requests from members of the CCAC, the final Action Plan fails to provide a proper context for readers as to the current state of emissions in Pennsylvania.

Readers of the Action Plan would be left to conclude that, but for implementation of the recommendations put forth, nothing is occurring to reduce carbon emissions and the situation is only worsening. In reality, we know that total greenhouse gas emissions – including all emissions across all sectors – has declined over 11% between 2005 and 2016. In Pennsylvania, we also know that total greenhouse gas emissions from the electric power generation sector – which is the overwhelming primary focus of the Action Plan, have decreased by 30% through 2015 (compared to a 2005 baseline year).

These reductions are historic and significant, and are overwhelmingly driven by market dynamics rather than government mandate. While these reductions do not negate the need for a robust discussion on how to achieve even further reductions, at a minimum they ought to be reflected in the Action Plan. In addition to proposing policy recommendations, the Action Plan serves as a primary educational document on the issue of climate change. This is a missed opportunity for the Department, and one in which it was repeatedly urged not to make by members of the CCAC.

Business as Usual Assumptions

The "business as usual" (BAU) scenario fails to consider historic trends in greenhouse gas (GHG) emission reductions. The BAU model overestimates future energy consumption increases across various energy sectors while failing to take into account the likelihood of continued energy

reductions across nearly all sectors that the state has experienced over the past decade. According to U.S Energy Information Administration (EIA) data, since 2005 Pennsylvania's GHG emissions have declined from a peak of 283 MMTCO2e in 2005 to a low of 219 MMTCO2e in 2016. That is a 22.6% reduction in greenhouse gas emissions over the decade. However, the report projects a net emission increase from 254 MMTCO2e in 2015 to 259 MMTCO2e in 2025 and 265 in 2050, or a 4.3% increase in greenhouse gas emissions over that timeframe.

The largest area of decrease in GHG emissions during the past decade has been in the energy generation sector, which has seen a 34% reduction from 124.5 MMTCO2e in 2005 to 82.1 MMTCO2e in 2016. During that period, retail sales of electricity have declined steadily from 148,272,940 megawatt hours MWh in 2005 to 142,990,896 MWh in 2017, or a 3.5% decrease. This decrease is the result of a number of factors, including implementation of Act 129 of 2008 which expanded the Public Utility Commission Commission's oversight responsibilities and established an Energy Efficiency Resource Standard requiring Pennsylvania's seven largest electric distribution companies (EDCs) to implement energy efficiency and conservation (EE&C) plans to reduce the amount of electricity consumed by customers.

Act 129 successfully reduced energy consumption at a rate of 3,370,673 MW per year during Phase II of the program (2013-2017). While the BAU model claims to include the effectiveness of policies and programs including Act 129, the program is currently in the second year of Phase III and will continue to produce energy savings across all energy sectors. Yet, the report BAU projection still concludes that emission from energy consumption will increase by 11 MMTCO2e by 2025.

Transportation sector emissions produced the second largest reduction in GHG emission between 2005-2016 with a decrease from 72.3 MMTCO2e to 60.7 MMTCO2e, or a 16% reduction. However, the report projects emissions from transportation sector electricity consumption to increase by four times as electric vehicle adoption grows across Pennsylvania. The report fails to take into account the reduction in emission from transportation fuel consumption. These figures indicate how the BAU scenario in the report overestimates future GHG emission and inflates the need for additional reductions by underestimating the continued effectiveness of previous efforts to reduce greenhouse gases across nearly all energy sectors.

Over-reliance on Energy Sector

The Department's findings and solutions rely heavily on policies and procedures aimed purely at the electricity generation sector, rather than a more balanced approach looking at other sources such as multimodal transportation. Even though energy production makes up 32% of the state's GHG emissions, CO2e from power generation is down 29.5% since 2005 (thru 2015); and down 30% nationally in the last 5-8 years. The transportation sector makes up 21% of Pennsylvania's total GHG emissions, and 28% of total US GHG emissions in 2016, according to the EPA.

The plan lays out very specific policy positions and recommendations related to the energy sector, including expansion of the Alternative Energy Portfolio Standards, maintaining nuclear generation in the state and detailed impacts to energy production. The plan lays out a platform for the Governor to enact policies for a statewide emissions trading program for electricity generation yet

provides no such detail for a transportation, other than the Governor's commitment for the state to join the regional Transportation and Climate Initiative. Regardless of that action the plan falls short on specifics for tackling other specifics outside of the electricity sector. The plan sets loose strategies for the implementation of sustainable transportation. Three topics were highlighted: the reduction of vehicle miles traveled for single-occupancy vehicles, implementation of a strategic plan and incentives for increasing electric vehicle use, and increasing the use of clean public transportation through electric municipal bus fleets.

Over-reliance on just the electricity sector, which, unfortunately, is often up for political debate, could lead to Pennsylvania missing their goals. Additionally, failing to adequately address concerns with specific policies in the Transportation sector would be a missed opportunity, one that the Action Plan itself claims to reduce over 21,689,937 MtCO2e by 2050, just by incentivizing and increasing electric vehicle use.

Cost-effectiveness of Strategy Options

The Department uses several factors to evaluate the cost-effectiveness of strategy options and recommendations that are included in the Action Plan. A key component of this evaluation is the social cost of carbon. The Department utilizes a social cost of carbon of $95/ton for 2050, which is *one of* the projected costs under a 2016 U.S. Environmental Protection Agency (U.S. EPA) integrated assessment model, utilizing a 2.5% discount rate.

However, in 2018 the U.S. EPA revised these cost estimates related to social cost of carbon. The U.S. EPA recognized that its prior iteration evaluated and extrapolated costs associated with climate change across the entire globe, a significant departure from virtually every other rulemaking which is to evaluate the impacts and costs of U.S. rulemakings within the United States. Further evaluation led to utilization of a discount rate of 3%, which translates to a social cost of carbon in 2020 of $12/ton and $26/ton in 2050 – or nearly 73% lower than the cost assumptions utilized in the Department's Action Plan.

Utilization of an outdated social cost of carbon – much less a failure to acknowledge the current cost recognized by the U.S. EPA – renders most if not all of the recommendations in the Action Plan as ineffective from a cost-benefit perspective. This is a significant shortcoming of the Action Plan.

Conclusion

Thank you for your inclusion of these comments in the Action Plan.

Zachery Smith

Jaret Gibbons

Patrick Henderson

Terry Bossert

Gary Merritt

Luke Brubaker